EVALUATION OF STRATEGIES FOR THE MANAGEMENT OF REGIONAL BLOOD CENTRE
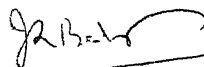
A Thesis Submitted
In Partial Fulfilment of the Requirements
for the Degree of
MASTER OF TECHNOLOGY

By
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to the
INDUSTRIAL & MANAGEMENT ENGINEERING PROGRAMME
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JULY, 1978

CERTIFICATE

This is to certify that this work on 'EVALUATION OF STRATEGIES FOR THE MANAGEMENT OF REGIONAL BLOOD CENTRE', by Indu Shekhar Singh has been carried out under my supervision and has not been submitted elsewhere for the award of any degree.

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July, 1978

IMEP- 1570 - M - SIN - EVA

ACKNOWLEDGEMENTS

I have been able to complete the work due to the grace and kindness of Almighty through following persons. I am indebted and grateful to all of them and express my sincere thanks, then, to:

Dr. J.L. Batra, whose kind guidance and regular supervision has led the work to this stage in time.

Dr. A.K. Mittal and Dr. Kripa Shankar for their suggestions at some stage.

The Officer-in-Charge and staff of both Red Cross and Sasson Government Hospital (Blood Bank Section) at Poona, who enthusiastically passed on to me the relevant information and data.

Gopal, my brother and his friend K.Chandra for their assistance in collection of data at Poona.

S.K. Agrawal, V.K. Nair, S.K. Gupta, A.A. Ghate and others of IME Programme, who helped me some way or the other.

The staff and persons at Computer Centre and Central Library, who assisted in some way.

Mr. J.K. Mishra for his superb typing work.

Mr. D.K. Mishra for his fine tracing work.

Mr. Buddhi Ram for his neat cyclostyling work.

All the staff of IME Programme, who cooperated with me at all stage.

All those who have directly or indirectly inspired and helped.

Indu Shekhar

CONTENTS

SYNOPSIS

The present work deals with the evaluation of strategies
for the management of a Regional Blood Centre. The two strategies
considered are referred as Single Cross Matching (SCM) and Double
Cross Matching (DCM). In single cross matching only one unit
(a bottle of blood) is reserved against each unit requested by
the patient while in double cross matching an attempt is made
to reserve two units in the name of one patient for each unit's
reservation request by him. Actually only two units are reserved
for two reservation requests by different patients, but the
units reserved in their names are paired such that each paired
unit is reserved in the name of both the patient and in the event
of call for the unit by them older of the two units are issued
first irrespective of their reservation. For each paired unit
the patients are referred as primary and secondary patients. The
unit for which reservation request is received from a patient
is referred as primary patient and the other paired patient as
secondary patient. The primary patient for a unit is the
secondary patient of the other unit of doubly cross matched pair.

A simulation model was developed for the above stated
strategies. The performances of the two strategies were studied
considering various criteria viz., blood utilization efficiency,
shortage and wastage reduction. Computer packages were developed

for the simulation model considering 1 day and 3 days of holding periods for reservation. Results for forty eight simulation runs were obtained and analyzed. The input data was generated within the desired limit of the parameters. In the case of double cross matching the effect of pair minimum age difference on the criteria was also studied.

A case study was developed based on the data obtained from Red Cross Unit, Poona and Sasson Govt. Hospital, Poona. Since the data was not complete for simulation analysis the other desired data were generated in a manner similar to generated data case. The results based on the case study for both the strategies were critically analyzed.

On the basis of generated data and case study, results indicated that in most of the cases the performance of double cross matching strategy is slightly superior to single cross matching in terms of lower shortage and higher percentage utilization efficiency. The case study indicated slightly better performance of single cross matching strategy in terms of blood wastage.

Based on the study, the adoption of double cross matching strategy has been recommended for Regional Blood Centre dealing with large number of units.

CHAPTER 1

INTRODUCTION

The industrial revolution lead the people to realise the importance of technology and latter the Theory of Scientific Management by Taylor added significant effect not only on the industrial scene but also on the social and human welfare fields, because ultimately a significant interaction exists between them. Although the Taylor theory was confined to cost reduction or profit maximization but its effect was so great that it changed the basic outlook towards any venture whether industrial or social.

The present work is mainly concerned with human welfare problem. It deals with policy formulation for regional blood centres with a view to reduce the blood wastage and shortages. Unlike other commodities the management of blood inventory and its distribution has to be considered in a different way due to its ethical and valuable significance.

1.1 CHARACTERISTICS OF BLOOD FOR TRANSFUSION:

Some of the important characteristics of blood inventory are:

(1) Human blood is the most vital commodity for human beings. It saves the very existence of the human beings in emergent situations.

2.   Blood is a perishable commodity. Its widely accepted life for transfusion purposes is only 21 days.

3.   The blood before transfusion is to be properly matched as only similar group of blood can be transfused to a particular human being.

1.2 EXISTING PRACTICES AND PROBLEMS.

There are numerous practices being followed all over the world with regard to the blood inventory and its distribution. In India, the following practices are being most commonly used by the blood centres.

i)   The blood is procured from voluntary donors and relatives of needy patients.

ii)   The blood is stored in bottles of 450 ml. capacity in cool and dark place (usually at 4°C).

iii) Once the blood is procured it is checked for its group (A, B,O,AB) and Rh-factor (positive or negative) and these information are labelled on the bottle.

iv)   On getting a request from patients, the blood is issued from the stock, if matching blood is available, otherwise refused.

v)   The system of reservation and call with holding periods is not used generally,which leads to uncertainity for availability of blood for transfusion purposes.

vi)   Once the blood is issued, it is not returned to the blood centre in any case even if it is not used and still has some useful life for transfusion, which otherwise could have been issued to other patients.

1.3   MOTIVATION AND DOMAIN OF PRESENT WORK:

During the past one decade number of publications
have appeared in the literature on blood inventory management
and distribution.   In the literature two distinct approaches
have been suggested.   These   referred as Single Cross
Matching (SCM) and Double Cross Matching (DCM) have been
suggested.   However no serious efforts seem to have been made
to evaluate the relative performance of these two approaches.

In this thesis, therefore, an attempt is made to study
the relative performances of single and double cross matching
strategies for regional blood centres.   The various criteria
considered for evaluation include measures like shortage,
wastage and utilization of the procured blood.   The complete
details of single cross matching and double cross matching
strategies have been presented in Chapter 3.

The mathematical modelling of the above mentioned two
strategies is very complex and as such simulation approach has
been developed for the evaluation of the two strategies. The
relevant information have been generated using uniform random
distributions with in suitable limits (details presented in
Chapter 3) keeping in view the computer memory constraints.
The actual data has also been procured from Red Cross unit,
Poona and Sasson Govt. Hospital,Poona.   The data collected
could not give all the needed information for the simulation

model. All the collected information was utilized and other necessary information has been generated suitably.

1.4 ORGANIZATION OF THESIS:

In Chapter 2, the literature on the blood inventory covering its various aspects, viz., management control, issuing policies, computerized information system and operational policies, have been briefly reviewed.

In Chapter 3, a formal statement of the problem is presented and the single cross matching and double cross matching strategies have been described. Further, the various assumptions underlying the development of simulation model and the detailed description of the subsystems of the model is given.

In Chapter 4, the simulation results have been tabulated for the generated data as well as the case study. Results have been discussed and analyzed to evolve suitable strategy for the management of regional blood centres. Further a few suggestions have been made for the future work in this area.

CHAPTER 2

LITERATURE REVIEW

The first mathematical model for scientific inventory management was developed by T.H. Harris in 1915 and since then large number of contributions have appeared in the literature on inventory management. Most of these papers deal with industrial products and relatively very little has been published in the area of Blood Inventory Management. In this chapter, we shall review some of the important contributions in this area.

Chazan and Gal[2] have analyzed the outdating rate and age distribution of blood. They assumed that after each period's demand the inventory is replenished with fresh unit upto a constant level and the age distribution has been treated as a Finite Markov Chain. They obtained the lower and upper bounds for the expected outdating in the case of general demand distribution. The authors have also pointed out that better and easily computable bounds can be found for the Poisson demand case.

Mole[11] in his paper pointed out that policy decision should be one which balances the conflicting stock requirements of maintaining a high availability and also low outdating rates. Markovian structure was used for the development of the mathematical model and effects of the key variables were studied and found to be interrelated. For the sake of simplicity, Mole has carried out the analysis on weekly basis rather than the usual daily basis.

Brodheim et al.[1] have also modelled the distribution policies for scheduled deliverance of perishable products subject to variable demand using Markov Chain with a manageable number of states. Using stationary distribution measures like probability of shortage, the average age of inventory and the average number of discarded blood bottles per time period were obtained. Easily computable bounds on these measures were developed which indicated as to how the measures mentioned above behave as a function of demand and inventory policy parameters.

Pegels and Jelmert[12] have studied the various human blood issuing policies on the basis of theoretical model using mainly the theory of absorbing Markov chains. They observed that the issuing policies affect the average inventory level, which in turn determine the shortage probabilities and the average age of the blood at the time it is being transfused.

Modified LIFO (which is issue fresher blood with higher probability than older blood) and modified FIFO along with LIFO and FIFO policies were considered for complete evaluation of the policies, so that a choice can be made on the basis of evaluation.

Pierskalla and Roach[1] have considered the various issuing policies under several possible objective functions. The blood inventory is grouped into categories according to shelf age. Whenever demand occurs for a particular category, the demand is satisfied either from the inventory units in that category or any younger category. It is shown that for most of the objective functions considered by the authors, the optimal policy is to issue the oldest unit first (FIFO) which will satisfy the demand.

Cumming et al.[5] have suggested a planning model for Regional Blood Suppliers in alleviating seasonal imbalances between supply and demand of blood. Various performance measures for a blood supply region were tested on a Markovian population model through graphs for a planning period varying between 3 - 12 months. The planning model iteratively develops improved collection plans. The authors claim that the iterative planning model is sufficiently accurate and highly effective for its cost. The model has been implemented by two regional blood suppliers using remote computer control. Basically this paper deals with the development of blood procurement policy.

Frankfurter et al.[7] have suggested a methodology for the design, development, implementation and operation of short term blood inventory level forecast system, which helps the blood centre management in taking corrective action to either reduce or increase the blood collections.

Leibman[10] has developed a computer oriented Management Information System for blood inventory. The information system generates routine management reports on outdated blood, blood two days from outdating, available supplies and blood requirements. The author claims that the use of his inventory information system resulted in reduced average amount of blood assigned but not subsequently used.

Jennings[9] points out the inventory control problem of blood bank is extremely complex innature and involves four main functions of procurement, store, process and supply. The complexity of the problem has been attributed to the following four reasons.

(i)   Both supply and procurement are random.

(ii)   Approximately 50 percent of the blood demanded, cross-matched and held for a particular patient are eventually found not to be required for that patient.

(iii)   Blood is a perishable item with a legal life of 21 days.

(iv)   Each blood centre interacts typically with a number of hospitals.

The author has developed models for the management of blood inventory on regional basis. Further alternative inventory policies have been analysed.

Dumas and Rabinowitz[6] have given new operational policies for reducing wastage (due to blood exceeding its transfusable age limit) without adversely affecting shortages (stock outs). They have further suggested the policy of DOUBLE CROSS MATCHING. This policy tests the same unit of blood for compatibility with two potential recipients (so that it is available for use by either) and also insures that blood is available for both. Further they have suggested another policy of using Rh-negative blood for Rh-positive patients under certain blood age conditions when medically feasible. The simultaneous use of both policies were also investigated. The performance of these policies were measured by wastage cost effectiveness over a range of demand levels. The operationa procedures for using these policies have also been discussed.

Pegels and Wallace[10] have suggested a computerized instant access information system. The system considers 21 days life of human blood for useful transfusion. Important component; of the information system are:

(1) an inventory system which keeps track of each individual unit of blood with its age and flags when it is due to outdate.

(ii)   a short term inventory level forecasting system which forecasts the system inventory level on a daily basis for the next two weeks on the basis of current inventory, forecasted demand and forecasted supply.

(iii)   an allocation model which allocates the blood in such a way that shortages and transportation cost are minimized. Further operating results have been given for the system.

Frankfurter et al.[8] have developed a computerized blood inventory system for a set of affiliated hospitals. Daily information regarding blood bottle code number, blood type, expiry date,date of procurement by the hospital, number of bottles in stocks are daily recorded and updated on the computer. Affiliated hospitals contact the computer system directly to acquire their inventory reports. These reports include variety of summary statistics to assist the hospitals in better planning and control of blood.

Pegels et al.[14] have evolved a planning system which utilizes conversational computer facilities to assist the manager of a regional or community wide blood agency in scheduling blood mobiles and fixed facility collections from one to eighteen months in advance.

Further the above authors along with Shubsda have examined the following four policies for their effect on shortage, efficiency etc., using a computer-based planning system.

(i)   Use of frozen red cells: technological alternative.

(ii)   Extension of useful life of blood: legal alternative.

(iii)   Improved collection planning: planning alternative.

(iv)   Improved inventory management: management alternative.

The comparative performance of each policy with respect to the principal objectives have been discussed in detail in reference[15].

Cohen and Pierskalla[3] have developed a system model using the techniques of management science and mathematical inventory theory to identify policy areas and formulate management objectives. Two simulation models have been used in analysis with actual data from different source. The results presented examine the interactions and savings associated with the use of optimal ordering, cross match and issuing policies. Further the authors have examined the question of contralized versus decentralized control.

Cohen et al.[4] have applied O.R. techniques to blood service complex. Mathematical response functions have been developed from the analysis of the data in each segment. The various segments considered include demand, forecasting, cross match and recycle control at each level of hierarchy in a regional system. They have further stated that these hierarchical models can reduce outdating, size of inventories and shortages.

Pegels and Seagle[16] have considered the extended
life of blood for useful transfusion and observed that it
will significantly reduce the outdating and maintaining higher
inventory levels. The study is based on the use of probabilistic
model. An obvious adverse effect of the above strategy is the
transfusion of older blood which may not be good from medical
reasons.

The above survey reveal that very little work has been
done on cross matching strategy for the management control of
blood inventory. Eventhough some work has been reported for
DOUBLE CROSS MATCHING, in this thesis an attempt is made to
further extend the concepts of double cross matching and
compare it with single cross matching.

CHAPTER 3

PROBLEM FORMULATION AND SOLUTION METHODOLOGY

3.1 PROBLEM STATEMENT:

Blood is collected from human body and stocked suitably so that it can be used for human being for transfusion purpose, when the need occurs. As only the matching blood can be transfused and the demand for the blood should be satisfied to the maximum possible extent, sufficient stock with suitable collection and distribution policy has to be established with the following main objectives.

(i) Shortage should be at the least possible level, as it has direct impact on the very existence of human being.

(ii) Wastage also should be at the minimum possible level for efficient utilization of the procured blood, thereby leading to easy procurement from voluntary donors.

Further the cost associated with the development of any suggested strategy for the fulfilment of above objectives should be minimum or atleast comparable with the gains in the system efficiency.

3.2 SYSTEM DESCRIPTION.

The procurement of blood at blood centre is mainly through the voluntary donors. In most of the situations, persons go to blood bank and donate their blood mainly on ethical considerations. However, sometimes they might be donating the blood for getting a certificate from the bank to this effect, so that on the basis of that certificate he can get blood any time in future for himself or his nearby relatives in case of emergent need. Blood centre accepts their blood after some primary checks and stores them in bottles of certain volume. Then the group of the blood is determined after test and the bottle is labelled with its group number, date of procurement and bottle number.

Further on getting a request from hospital for blood bottle along with the sample of the blood, the sample is matched with the blood bottle in unassigned stock after the determination of its group. Hence on availability of properly matched blood the request for reservation is satisfied, otherwise shortage is declared. In both the situations hospital is informed accordingly.

Blood centre identifies blood bottles in three separate stacks and accordingly the stocks are known as (i) Unassigned stock, (ii) Reserved or assigned stock, (iii) Outdated stock.

Unassigned stock consists of initial unreserved units, freshly procured units, unused returned units from hospitals (within reuse age limit) and cancelled units from reserved stock (within reuse age limit) as shown in Fig. 3.1(a).

Reserved stock consists of units reserved from unassigned stock on getting request for the same from hospitals and availability of the units in unassigned stock as shown in Fig. 3.1(b).

Outdated stock consists of units returned from hospitals exceeding the reuse age limit, cancelled units from reserved stock exceeding the reuse age limit and the units exceeding the reuse age limit from unassigned and assigned stock as shown in Fig. 3.1(c).

3.3 BLOOD MATCHING STRATEGIES.

The aim of the present work is to evolve and evaluate alternate strategies for the management of a regional blood centre such that the maximum number of patients are satisfied and the overall wastage of blood is minimum. The problem described in Section 3.2 has been attacked by the following two approaches.

(i)   Single Cross Matching : (SCM)

(ii)   Double Cross Matching : (DCM)

Procured   Unused returned units
Units   (within reuse age limit)

Initial ———→ | Unassigned   Stock | ←——— Cancelled units
unreserved   (within reuse
units   age limit)

Fig. 3.1(a)

Units reserved from. unassigned stock

| Reserved Stock |

Fig. 3.1(b)

Unused returned units   Cancelled units
(exceeding reuse age   (exceeding reuse age limit)
limit)

Unassigned stock | Outdated   Stock | ←——— Assigned stock unit
units (exceeding   (exceeding reuse
reuse age limit   age limit)
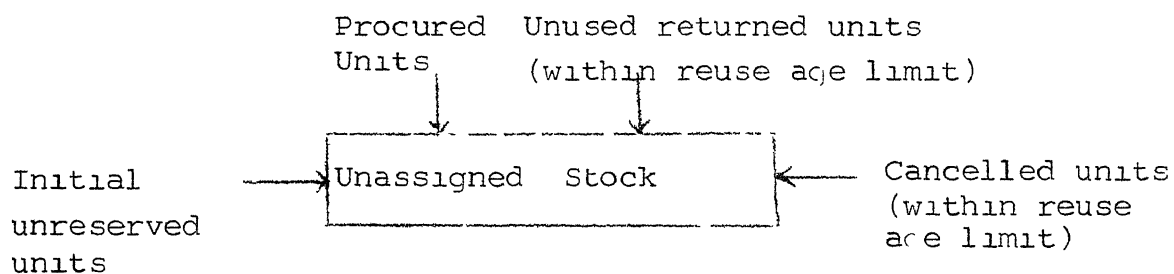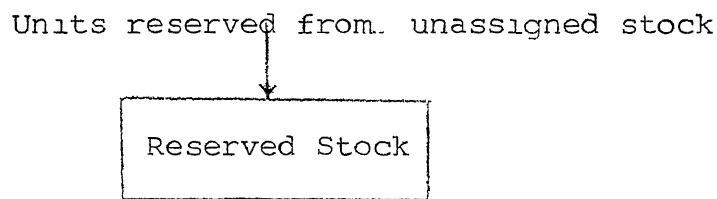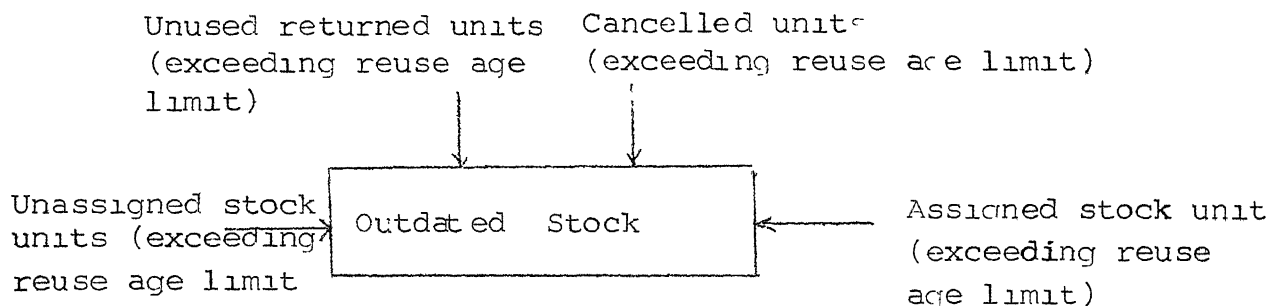
Fig. 3.1(c)

3.3.1 Single Cross Matching:

In this policy, on getting a request from doctor or hospital, the blood bank or blood centre reserves the bottle after proper match in the name of the patient for which the request was received, if the bottle is available in the unassigned stock by following the FIFO policy. If the same is not available shortage is declared. In both the situations the doctor or the hospital is informed accordingly.

The reserved units are kept for individual patients for certain period known as the holding period for reservation. Within this period the reserved blood can be called by the doctor or hospital for transfusion. If it is not called within this period, the reservation is cancelled and these bottle/s of blood joins the unassigned stock. The blood centre will maintains three separate stocks viz., assigned stock, unassigned stock and outdated stock. Further, the called blood can be kept by the hospital for certain period known as 'holding period for call', so that it can be transfused in actual need within that period. If the called blood is not used, then at the end of holding period for call it is returned to the blood centre.

3.3.2 Double Cross Matching:

In this policy, for any given two patients (pair of patients) each requiring a unit of blood of the same type, two

matched units of blood are reserved in a paired fashion. Each
of the two reserved paired units is made available to either
of the patients. Corresponding to each blood unit patients
are assigned in the same manner as in single cross matching.
The pair of blood bottles to be formed is identified considering
the blood age difference of the assigned bottles (a decision
variable). The use of single cross matchin identifies the
primary patient for the paired blood units. For each blood
unit in the pair, the second patient in the pair gets the
status of secondary patient. The reservation scheme in this
policy may be represented as shown below:

Bottle Number	Primary Patient	Secondary Patient
1	A	B
.		
.		
.		
n	B	A

It needs to be noted that the reservati n of only
single unit of blood for the two patients is not proper, as there
is a reasonable chance that both patients will need blood. Hence
a second unit is cross matched against both patients and
reserved. Thus in the double cross matching neither
patient is in danger of being denied a unit of blood in the
event of calls for blood by both of them.

In this policy, in the event of cancellation, at the
end of holding period for reservation with respect to primary
patient, the same unit of blood is now made singly reserved
in the name of secondary patient, but now as primary patient
and the unit of blood reserved for secondary patient earlier as
primary patient is now made the member of unassigned stock as
shown below:

Bottle Number	Primary Patient	Secondary Patient
1	B	X
.		
.		
.		
n	X	X

where X stands for possible entry that can be made after cancellation

Further in this policy, if the call is made by any one
of the paired patients, the older unit of blood is issued first
even if the call comes from the secondary patient. However if
the call is made by both of them, both the paired units are
issued.

Double cross matching does not increase the overall
probability of use but may be used to shift some probability
of use between units. If priority of use is based on age,
and if one unit is relatively close to its expiration date
and the other is relatively fresh, the above policy may reduce
wastage by increasing the probability of using the older unit
before expiration date – while increasing the probability that
the younger unit will grow little older.

This policy puts the same number of units on reserve as the conventional reservation system but greatly increases the number of cross matches performed, i.e., increases the work load considerably.

The present work is directed towards studying the relative performances of the above stated two strategies in regard to the objectives of minimization of blood wastage as well as its shortage. Further an attempt is made to select the best set of decision variables (stated below) for both the strategies.

(i) Holding period for reservation of one day and three days have been investigated in the present work.

(ii) The minimum age difference between the older and fresher units of blood forming the pair in case of double cross matching. Age difference of 3 to 14 days between older and fresher units of blood have been considered.

The problem as described earlier is too complex to be considered mathematically, therefore a simulation approach is adopted for the same.

The development of the simulation model is based on certain assumptions. Some of the important assumptions involved there in are stated below.

3.4 ASSUMPTIONS:

(i)   The useful life period of human blood for transfusion purposes is assumed to be 21 days, which is legally and widely accepted all over the world.

(ii)   The demand and supply of blood will be in terms of units of bottles (usually 450 ml in a bottle) even if the demand is in part, it should be treated as the next higher number.

(iii)   Only the reserved units can be called.

(iv)   The holding period for a called unit by the hospital is assumed to be 3 days. This holding period is referred as 'holding period for call'.

(v)   The reservations are made on the FIFO basis.

(vi)   At the blood centre, the procured blood bottles are assigned Permanent Bottle Number (PBN) serially in the order of their age.

(vii)   The procurement of blood   on any day is of fresh blood only and all fresh blood entering the blood centre is treated as blood which is one day old.

(viii) In this thesis the term 'unit' will be used to signify a bottle of blood or any part thereof.

(ix)   The initial stock comprises of units which are either 17 days old or below in age.

(x)   Keeping in view the computer memory limitation the limit for different parameters, such as, number of units in the initial stock, number of units demanded on a day, number of units called, number of units returned and number of units cancelled has been assumed to be 50. On the basis of this limit other related parameters, viz., maximum number of patients requesting reservation and the maximum number of units requested by each patient has been assumed to be 13 and 4 respectively. Procurement limit is also assumed as 50.

(xi)   The parameters mentioned under assumption (x) are assumed to be generated randomly from uniform distributions.

(xii)   All the analysis are with respect to any single type of blood.

3.5   SIMULATION MODEL DEVELOPMENT:

A simulation model which involves the consideration of various subsystems described below has been developed. A computer package for the simulation model has been developed for the IBM 7044 - 1401 system.

3.5.1   Model Description:

The model includes the following:

(i) Initialization: This deals with the initialization of variables and takes care of previous stock entry, if any.

(ii) Procurement: This subsystem deals with the daily collection of blood bottles.

(iii) Return of Unused Units: This subsystem enters back the information regarding the bottles of blood which were called earlier but could not be used and as such are returned.

(iv) Call of Units   This subsystem deals with the call of blood bottles which were reserved earlier and is within the holding period.

(v) Cancellation of Reserved Units: This subsystem cancels the reservations made earlier after the expiration of holding period for reservation.

(vi) Reservations: This subsystem deals with reservation of units on the receipt of reservation request from hospitals or doctor depending upon the unassigned stock in the centre, otherwise shortage is declared. Reservations are made either using single cross matching or double cross matching. Further the age of each collected unit is updated.

(vii) Statistics   This subsystem deals with the updating of the stock, calculation and printing of desired outputs.

For better comprehension of the blood centre problem, it would be worthwhile to state day-wise, as to what events

would take place in the blood centre. Foregoing discussion is based on 3 days holding period for both reservation and call.

On the first day there will be first procurement and first reservation. Besides the first procurement the unassigned stock will consist of the previous stock on ac.

On the second day there will be second procurement, first call and second reservation.

On the third day, there will be third procurement, second call and third reservation.

On the fourth day, there will be fourth procurement, third call, first cancellation and fourth reservation.

On the fifth day, there will be fifth procurement, first return, fourth call, second cancellation and fifth reservation.

Likewise from sixth day all important events take place on similar lines stated above for five days. It should be noted that the reservations of blood are done using either single cross matching or double cross matching.
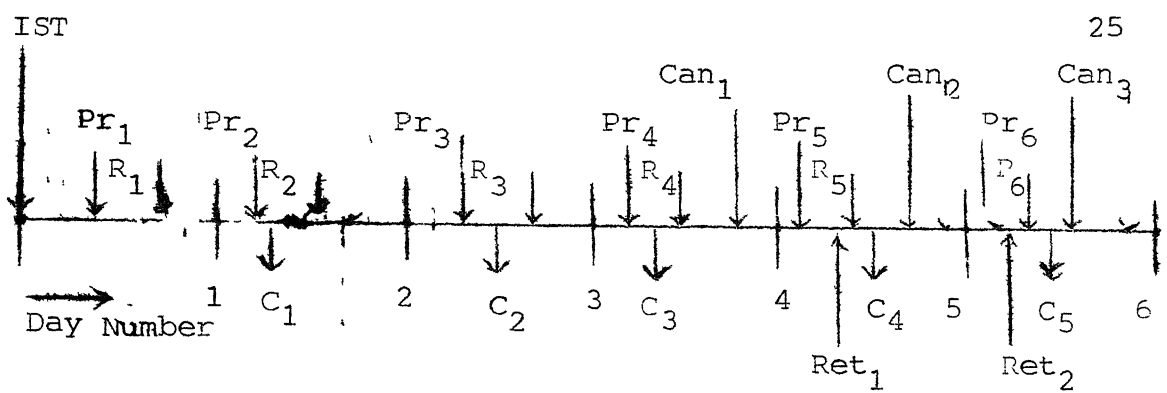
Fig. 3.2

In Fig. 3.2 IST represents the initialization cf the
systems while Pr, R, and C represent procurement of units,
reservation of units using a strategy, and call of units
reserved earlier respectively. Further, Can and Ret
represent the cancellation of reserved units which could not
be called and return of called but unused units respectively. The su
scripts $(1,2,\ldots, 6)$ indicates the sequence number of
occurrence of different events after the start of the simula-
tion. Fig. 3.3 depicts unit and information flow in the model.

From the diagram shown in Fig. 3.4, it is evident that
at the start of the simulation, all important parameters are
initialized and the day number is set equal to 1. The unassigned
stock file is updated by adding the day's procurement to the
previous unassigned stock if any. Depending upon the actual
conditions for occurrence of different events (explained
earlier in Fig. 3.2) following events take place in order.

(i)   Return of unused but called units by hospitals.

(ii)   Call of units reserved previously.
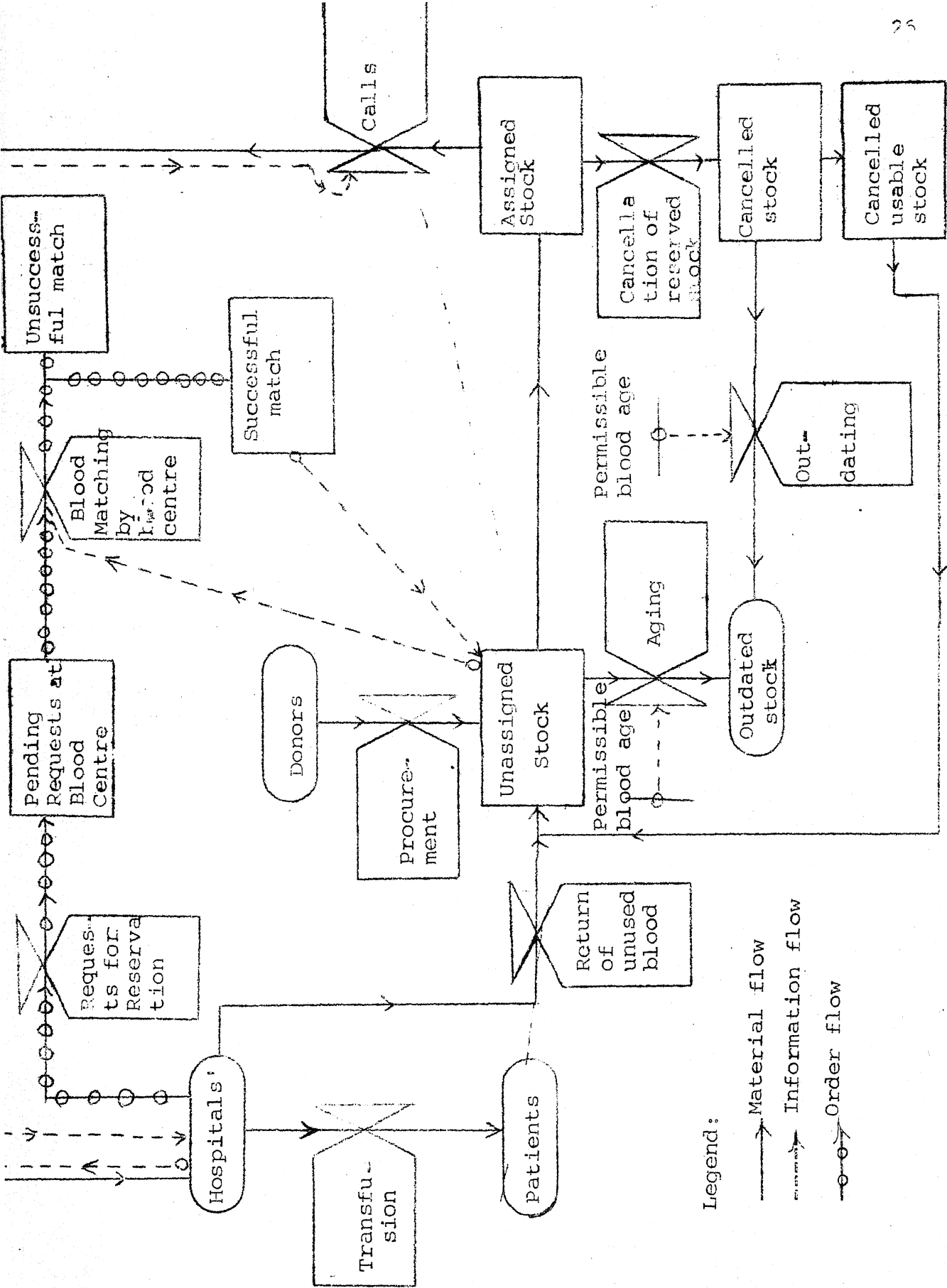
Fig. 3.3: Material and Information Flow Diagram for the Model

START

β

Initialization

Set Day Number as 1

Initial stocking

γ

Procurement

Return condition ?

No

Yes

UPDATE outdated and unassigned stock files

Return of unused units

Update Assigned stock file

Call of Reserved units

Yes

Call condition ?

No

Cancellation of Reserved units

Yes

Cancellation condition ?

No

Update outdate, unassigned and assigned stock files

Demand

α

Fig. 3,4: Flow Diagram of Simulation Model.

(iii)   Cancellation of units reserved but not called by the hospitals at the end of holding period for reservation.

(iv)   Reservation of units on the basis of demand occurring on the day.

(v)   Age updating.

(vi)   Statistics.

After this, the day number is increased by one and the same procedure from procurement is repeated till the limit set for next simulation is reached.   Then the final   results are printed and depending upon the requirement, the analysis is carried out again by initializing the whole system for next simulation, otherwise the simulation runs terminate.

3.5.2 Nomenclature:

The following are some of the important notations that have been used for the development of the computer package as well as for describing the various aspects of the subsystems with respect to a simulation run.

3.5.2.1 Variables:

DN   Day Number of the simulation run.

PBN   Permanent Bottle sequence Number labelled by the centre.

COLECT Collection of fresh units on a day by the centre.

TBD	Total number of Bottles Demanded from the centre.
TNP	Total Number of Patients for whom reservation requests came.
TSORTG	Total number of Shortages of units at the centre.
TCALL	Total number of units Called from the centre.
TUNCAL	Total number of Units Not Called from the centre.
TCNUSE	Total number of units Called but Not Used by the hospitals.
TBDAP	Total number of Bottle Doubly Assigned Pairs made at the centre.
TCLECT	Total number of unit Collected by the centre.
TBSA	Total number of Bottles Singly Assigned by the centre.
TPSA	Total number of Patients Singly Assigned by the centre.
TUNCGW	Total number of Units Not Called and are Going Waste.
TCNUCW	Total number of Called units Not Used and are Going Waste.
TAGW	Total number of units Actually Going Waste due to aging only.

UNASND   total number of Unassigned Units available at the centre.

ASIND   minimum number of units Assigned for requests met before.

ODATE   total number of units Outdated.

NOPR   Number of Patients Requesting for reservations on a day.

NOBC   Number of Bottles Called on a day by the hospitals.

NOBR   Number of Bottles Returned on a day by the hospitals.

3.5.2.2 Matrices:

The various matrices used for the development of the model are.

1. Match Matrix (MM): Relevant information for each unit collected at the blood centre such as identification number (a sequence number assigned to the blood unit at the centre after procurement), age, primary patient number after reservation, seconday patient number after double cross match pair formation and status are stored in a matrix known as Match Matrix (MM). The status of each unit is assigned values -1, -2, 1, 2, 3, 0 to represent the same. -1 indicates that the unit is below its reuse age limit and has not been reserved by any matching strategy, whereas -2 indicates that the unit was reserved

earlier and as its age is below reuse age limit after possible

return or cancellation of reservation of the unit, it can be

reserved again. The unit is assigned value 1,2,3,0 to

represent its status respectively depending upon whether the

unit has been singly reserved (i.e., reserved for only one

patient), doubly reserved (i.e., reserved for two patients),

has been called by the hospitals or has become outdated.

2. Assigned Matrix (ASINED): For each patient, the permanent

patient number (i.e., a sequence number assigned to the patient

after the start of a simulation run), its first reserved unit

number and the second reserved unit number (in case of success-

ful double cross match) are stored in a matrix known as

(ASINED) matrix.

3. Demand Matrix (DM): The information relevant with respect

to day's reservation requests such as sequence number of unit

demanded, sequence number of the patient on that day, permanent

unit number of satisfied demand, permanent patient number and

the status of request are stored in the matrix known as Demand

Matrix (DM). With respect to a reservation request, the

status in Demand Matrix is assigned values 1 or 0 for acceptance

of request for reservation and shortage respectively.

3.5.2.3 <u>Arrays</u>:

The various arrays used for the development of the model are:

1. PROCUR   This array (PROCUR) stores number of units procured of different age on a day.

2. IST   This array (IST) stores number of units of different age of initial stock.

3. INTAKE   This array (INTAKE) stores number of units collected on different day number.

4. DEMAND   This array (DEMAND) stores number of units demanded on different day number.

5. NUCALD   This array (NUCALD) stores number of units called on different day number.

6. CBNA   This array (CBNA) stores unit numbers which are called and related informations on a day having day number equal to integer multiple of 3 plus one i.e. for DN = 1, 4, 7, ...

7. CBNB   This array (CBNB) stores unit numbers which are called and related informations on a day having day number equal to integer multiple of 3 plus two, i.e., for DN = 2, 5, 8, ...

8. CBNC   This array (CBNC) stores unit numbers which were called and related informations on a day, having day number equal to integer multiple of 3, i.e., for DN = 3, 6, 9,...

9. RETBNA   This array (RETBNA) stores the unit numbers
            returned from hospitals and cancelled from
            reserved stock which can again be assigned
            alongwith related informations on a day.

10. RDCMBN   This array (RDCMBN) stores the unit numbers to be
            considered for double cross matching and related
            information on a day.

11. CBARAY   This array (CBARAY) contains the unit numbers
            reserved within three days and yet to be called
            by the hospitals.

12. RBARAY   This array (RBARAY) contains the unit numbers res-
            erved on the last three days by the centre.

The related informations in context with the above des-
cription are the day number, the number of units in the parti-
cular array and some identification number for proper recognition
as some of them may be of same dimension.

3.6.3 Subsystem Description:

In the subsequent subsections the different subsystems
of the proposed simulation model with reference to computer
package are discussed in detail.

3.5.3.1 Initialization:

All the variables representing different counts are
initialized as one or zero depending upon the purpose for which
they are to be used. Matrices alongwith arrays are initialized
as -1 to represent the beginning of simulation.

It is assumed that the blood centre will be having some previous stock consisting of units of varying age. This information is normally available with the blood centre and in absence of this information, the units of different age varying between 1 to 17 days are generated randomly using uniform distributions such that the number of units of any age may be between 0 and 3 in accordance with the assumption made in Section 3.4. A new permanent bottle number (PBN) is assigned to each unit and the Match Matrix (MM) is updated accordingly.

3.5.3.2 Procurement.

It is an essential input to the blood centre management system. The procurement of blood is through voluntary donors. Occasionally special camps are arranged by blood centre for collection of blood.

The number of units collected will be known to the blood centre and in absence of this information, it is generated randomly using uniform distribution in the range specified in assumption (Section 3.4). For the purpose of simplicity in analysis it was assumed that the collection is of fresh units only. This assumption is a valid practical assumption as in most of the cases the collection is mainly from donors. Each unit after some test and group classification is assigned a permanent bottle number (PBN) and is entered into the unassigned stock. The Match Matrix (MM) and related variables are updated accordingly.

3.5.3.3 Return of Unused But Called Units:

In this subsystem the units which were called earlier by the hospitals for transfusion purposes and could not be used due to some reason or the other (which may be due to less actual need by the patient) are returned to the blood centre. Depending upon the age of the returned units they are either allocated to the unassigned stock or outdated stock.

The number of units returned (NOBR) and their actual unit numbers will be made available to the 'blood centre by the hospitals and in absence of this information, for model analysis, the number of units returned (NOBR) is randomly generated using uniform distributions in the range equal to the number of units called three days back.To know the actual unit numbers of the units returned from the hospitals the array containing the information about units called three days back is identified and the (NOBR) units are selected from this array in a random fashion.

3.5.3.4 Call of Units:

The call of units starts from the second day of the simulation as only the reserved units can be called. The holding period for reservations has been assumed to be 3 days, i.e., a unit once reserved cannot be reserved for another request within three days of the last reservation of a unit.

The array (CBARAY) is updated by purging the unit numbers which were in this array for three days and entering the unit numbers reserved on previous day. The number of units called along with their unit numbers is supplied by the hospitals and in absence of this information, the number of units called is randomly generated using uniform distributions in the range equal to the number of units available in the array (CBARAY).

The actual unit numbers to be issued to hospitals is selected in a random fashion from array (CBARAY). The units are checked for their status. If the status of the unit is found to be 2, i.e., it has been doubly matched with another unit, then actually the older of the two paired units is sent to the hospital provided it satisfy the age restrictions. Three arrays (CBNA), (CBNB) and (CBNC) are maintained to record the information regarding the unit numbers called on each of the last three days, if any. Array (CBNA) contains the unit numbers called on the day, whose day number equals integer multiple of 3 plus one. Array(CBNB) contains the unit numbers called on the day, whose day number equals integer multiple of 3 plus two. Array (CBNC) contains the unit numbers called on the day, whose day number is integer multiple of 3. The proper array to enter information about the called units is selected and updated. The count for total number of units called and the array (NUCALD) are also updated.

3.5.3.5 Cancellation of Reservation:

In this subsystem the reservations of units which were reserved 3 days back and could not be called within that period is cancelled. These cancelled units either join the unassigned stock or outdated stock depending upon their age.

In the simulation model the units reserved 3 days back are checked for their status. If the status is found to be 1, the age of the unit is checked and if the unit is within reuse age limit, the unit number of this unit is entered in the array (RETBNA), otherwise declared outdated. The status is accordingly updated. However, if the status was found to be 2, i.e., the unit is paired with another unit, the paired unit's unit number is entered in an array (RDCMBN), to be used latter in the pair formation of double cross match strategy and the status is updated as 1. Next the second unit in the pair is checked for its age and if this unit is within reuse age limit, the unit number is entered in an array (RETBNA) otherwise declared out-dated. The status is updated accordingly.

3.5.3.6 Reservations:

In this subsystem reservations are done against the requests made by the hospitals. If the demand, i.e., the request for reservations cannot be met fully, it is met in part as far as possible using FIFO policy. The unfulfilled demand is declared as shortage. Hospitals are informed

accordingly. However if the hospital considers it necessary, it can again send the same request the following day. Such request for reservation are satisfied with by assigning the highest priority by the blood centre. An attempt is made to satisfy reservation requests firstly from the units which are returned from hospitals and then, if necessary, from the unreserved units. It is contemplated that above strategy would result in better utilization of the procured blood and in turn would also satisfy the demands more efficiently.

The number of patients and the units requested for each of them is supplied by the hospitals and in absence of this information the number of patients and the number of units demanded by each of them, are randomly generated using uniform distributions and the range is taken as 1-13 and 1-4 respectively as stated in Section 3.4.

The array (RBARAY) is updated to enter the present day's satisfied requests for reservations. Depending upon the availability of units in unassigned stock, request for reservation of units is met by reserving first the units stored in an array (RETBNA) against the request made using FIFO policy. The array (RBARAY), Match Matrix (MM), Demand Matrix (DM) and related count variables are updated accordingly. The updated Demand Matrix (DM) may be printed for details and information to be sent to hospitals.

Double Cross Matching:

Double cross matching is done for the units reserved
by the single cross matching strategy. It should be noted that
in general double cross matching has imbedded into it the
reservations by single cross matching. For every satisfied
request, the units are identified and the patients for whom
these units are reserved is declared as the primary patient.
An attempt is made to generate pairs among the units reserved
by single cross matching using the double cross matching
strategy.

The pairs are generated such that there exists a certain
minimum age difference among the paired units. The optimal
lower limit for the age difference can be determined based on
the wastage reduction criterion. The benefit of double cross
match in terms of wastage reduction mainly depends on the issue
of older paired unit in place of request for younger age
paired unit. Further it is contemplated that the chances of
wastage reduction improves with

(1) increase in the number of pairs formed by the double
     cross matching strategy,

(2) increase in the call for younger units by the hospitals.

The number of possible pairs that can be formed depends on the following:

(i)   Number and age distribution of singly reserved units.

(ii)   Number and age distribution of initial stock.

(iii)   Procurement distribution of units.

(iv)   The age difference between the paired units.

For pair formation the string of singly cross matched units, which contains units arranged in decreasing order of their age is split into two parts at the middle. The two parts of string are referred as string A and string B. The first unit in the string A is compared with the first unit in string B. If the age difference is appropriate, then the pair is formed, otherwise the unit of string A is compared with the subsequent unit in string B till the pair formation becomes admissible. On getting success in pair formation the status of paired unit is made 2 and the matrices (MM) and (ASINED) are updated accordingly along with related count variable. Similar proce dure is repeated for other pair formation from string A.Further while searching for units in string B, for pair formation, if all the units of string B are exhausted without obtaining a pair, the pair formation is not carried out for all the subsequent units in string A.

Age Updating:

In the model the age of units are updated at the end of day's analysis. The units which exceed the age limit for reservation are declared outdated on account of natural aging. The Match Matrix (MM) and related count variables are updated accordingly.

3.5.3.7 Statistics:

The computer package permits the printing of various daily statistics which include COLECT, TCLECT, TBD, TNP, TBSA, ASIND, TCALL,TSORTG, TBDAP, TUNCAL, TCNUSE, ODATE, TUNCGW, TCNUGN, TAGW, UNASND along with the day number (DN). At the end of a simulation run the various statistics are printed. These statistics are defined below:

Average bottle demanded per patient (AVBDPP)

$$= \frac{\text{Total bottle demanded (TBD)}}{\text{Total number of patients (TNP)}}$$

Percentage Shortage (SORTP)

$$= \frac{\text{Total shortages of units (TSORTG)}}{\text{Total bottles demanded (TBD)}} \times 100$$

Percentage wastage with respect to demand (WASTPD)

$$= \frac{\text{Actual number of units outdated (ODATE)}}{\text{Total bottles demanded (TBD)}} \times 100$$

Percentage wastage (WASTPC)

$$= \frac{\text{Actual number of units outdated (ODATE)}}{\text{Total units collected (TCLECT)}} \times 100$$

Percentage call (CALLP)

$$= \frac{\text{Total number of units called (TCALL)}}{\text{Total number of singly met reservations (TBSA)}} \times 100$$

Percentage unused (UNCALP)

$$= \frac{\text{Total number of called units not used (TCNUSE)}}{\text{Total number of units called (TCALL)}} \times 100$$

Percentage unreserved (UNRESP)

$$= \frac{\text{Total number of units not called, (TUNCAL)}}{\text{Total number of singly met reservations (TBSA)}} \times 100$$

Percentage increase in utilization efficiency (UEFFIN).

$$= \frac{\text{Singly met reservations} - \text{Minimum number units actually reserved}}{\text{Singly met reservations}}$$

$$= \frac{\text{(TBSA)} - \text{(ASIND)}}{\text{TBSA}} \times 100$$

Average inventory position (AVINVP)

$$= \frac{\text{Sum of each days unassigned stocks}}{\text{Number of days considered for a simulation}}$$

3.6 STRATEGIES EVALUATION APPROACH

The two matching strategies viz., single cross matching and double cross matching have been evaluated using the randomly generated data for both 1 day and 3 days reservation holding periods. The two computer packages were developed for the

simulation model, one with reservation holding period as 3 days and the other with reservation holding period as 1 day. The program was written in Fortran IV for IBM 7044-1401 systems. Five different random number generators have been used, which give uniformly distributed random numbers between 0 and 1. The parameters have been made to lie with in desired range of values by the use of appropriate multiplication factor.The relative performance of these strategies are presented in the next chapter. The listings of the computer package developed for two reservation holding periods 1 and 3 days are given in Appendix II and Appendix II.

Each simulation run is carried for a particular minimum age difference among the paired units for double cross match strategy. The pseudo random numbers used for getting random information with uniform distribution is initialized at the beginning of each simulation run.

The two strategies have also been evaluated based on the data obtained from Red Cross unit, Poona and Blood Bank Section of Sasson Government Hospital, Poona. The details of the case study along with the results obtained are presented in next chapter.

CHAPTER 4

EVALUATION OF STRATEGIES: RESULTS AND CONCLUSIONS

The model developed in previous chapter and the computer
packages prepared for the same were used for studying the
relative performances of the two matching strategies for 1 day
and 3 days reservations holding periods. Further the performance
of DCM strategy for various minimum pair age difference was
studied. The results were obtained separately for the generated
data and the case study.

For the study based on generated data, the data has been
generated using five different pseudo random number generators,
keeping in view the suitable ranges of the various parameters.
The ranges selected for the parameters have already been men
tioned in Section 3.4.

For the case study, the data were collected from the Red
Cross unit, Poona and the Blood Bank Section of Sasson Govt.
Hospital, Poona. Since the blood banks in India are mainly
concerned with the   collection of blood and not as in USA and
European countries, with the overall management of it, the data
collected could not give all the information needed for the
simulation model. All the collected information has been used

and other necessary information has been generated suitably
keeping the various assumptions listed in Section 3.4 in view.
The results obtained for both the generated data and the case
study have been analysed.

4.1 RESULTS FOR GENERATED DATA:

For the generated data, the results of forty eight
simulation runs obtained for 1 day and 3 days reservation
holding periods using single cross matching and double cross
matching strategies are presented in Tables 4.1 and 4.2. Each
run corresponds to a particular DCM pair minimum age difference
varying from 3 to 14 days.

Figures 4.1 and 4.2 graphically represent the percentage
increase in utilization efficiency and percentage wastage versus
DCM pair minimum age difference respectively, using the results
listed in Tables 4.1 and 4.2. As the percentage shortage was
zero in all situations, the same has not been shown graphically.

On the basis of results obtained, the following observa-
tions are made.

(i)   There was no shortage in any situation.

(ii)   Both the percentage increase in utilization efficiency
and percentage wastage are more for 1 day holding period
compared to 3 days holding period for reservations.

Table 4.1:   Results for generated data using single
             cross match strategy.

Reservation Holding period (in Days)	Percentage Shortage	Percentage Wastage	Percentage increase in Utilization Efficiency
1	0.0	28.32	31.05
3	0.0	14.34	19.96

Table 4.2· Results for generated data using double
            cross match strategy.

DCM Pair Min. Age Difference (in Days)	Holding period for reservation					
	3 Days			1 Day		
	Percentage Shortage	Percentage Wastage	Percentage increase in utilization efficiency	Percentage Shortage	Percentage wastage	Percentage increase in utilization efficienc
14	0.0	14.34	19.96	0.0	28.32	31.05
13	0.0	14.34	19.96	0.0	28.32	31.05
12	0.0	14.34	19.96	0.0	28.32	31.05
11	0.0	14.34	19.96	0.0	28.44	31.05
10	0.0	14.45	19.96	0.0	28.55	31.05
9	0.0	14.45	19.96	0.0	28.44	31.05
8	0.0	14.45	19.76	0.0	29.60	31.45
7	0.0	14.45	19.96	0.0	27.98	30.85
6	0.0	14.57	19.56	0.0	27.86	30.85
5	0.0	14.57	19.96	0.0	30.17	31.65
4	0.0	5.20	21.17	0.0	29.71	31.65
3	0.0	11.79	21.77	0.0	28.55	31.25

Fig. 4·1 Comparison of increase in utilization efficiency for SCM & DCM (Generated data)
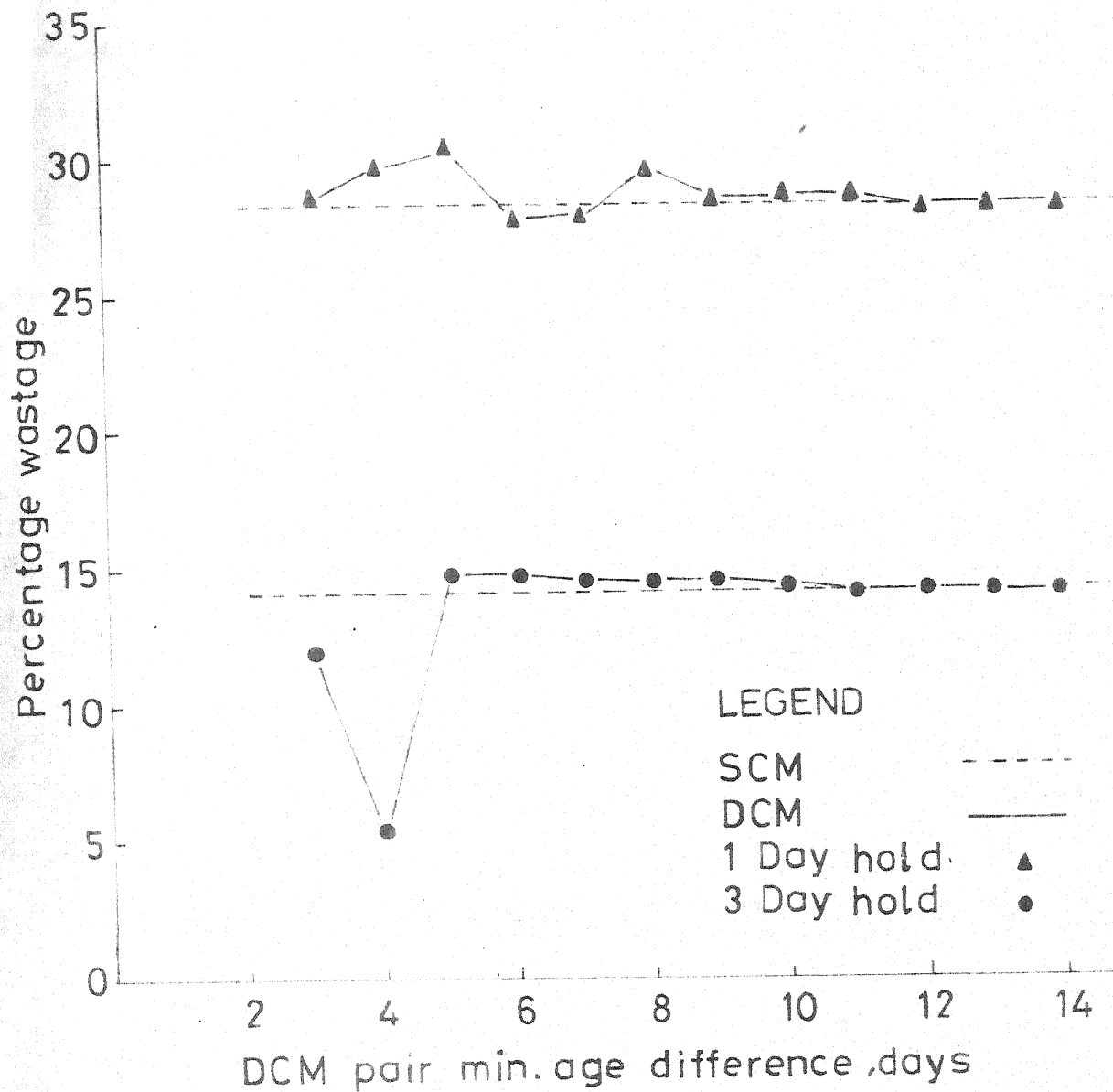
Fig.4·2 Comparison of percentage wastage for SCM & DCM (Generated data)

(iii)   The minimum wastage was 5% for 3 days holding period for reservation, using double cross match strategy with minimum age difference among pairs as 4 days. The corresponding increase in utilization efficiency was 21%.

On the basis of the results obtained, the use of double cross match strategy is suggested with 3 days holding period for reservation and DCM pair minimum age difference as 4 days.

4.2   RESULTS FOR CASE STUDY

The results obtained for the case study with 1 day and 3 days holding period for reservation using single and double cross matching   strategies are presented in Tables 4.3 and 4.4.   For each holding period for reservation twelve simulation runs were carried out for single cross matching and another twelve simulation runs for the double cross matching. Each run corresponds to a particular DCM pair minimum age difference. The values selected varied in the range 3 to 14 days.

The results obtained have also been represented graphically.   Figures 4.3 to 4.5 graphically represent the percentage shortage, the percentage wastage and percentage increase in utilization efficiency versus DCM pair minimum age difference respectively, using results listed in Tables 4.3 and 4.4.

Table 4.3: Results for case study data using
single cross match strategy.

Reservation Holding Period (in Days)	Percentage Shortage	Percentage Wastage	Percentage Increase in Utilization Efficiency
1	6.45	13.28	46.98
3	14.92	5.65	27.49

Table 4.4 Results for case study data using double
cross match strategy.

DCM Pair Min.Age Difference (in Days)	Holding period for reservation					
	3 Days			1 Day		
	Percentage Shortage	Percentage Wastage	Percentage Increase in Utilization Efficiency	Percentage Shortage	Percentage Wastage	Percentage Increase in Utilization Efficiency
14	9.48	5.37	30.96	6.45	12.71	47.41
13	8.06	5.93	30.70	4.84	14.69	45.13
12	15.12	7.63	28.27	4.44	13.84	46.62
11	11.90	6.50	33.18	4.64	14.41	45.88
10	16.53	7.06	23.91	7.06	14.12	46.64
9	11.90	6.50	33.64	6.65	12.71	47.95
8	15.52	6.78	29.83	6.25	12.99	46.67
7	9.88	5.93	31.54	4.03	15.25	46.85
6	14.72	8.19	31.21	6.05	14.69	44.21
5	9.48	5.08	29.40	6.25	12.71	47.31
4	12.50	4.24	28.11	4.84	12.15	45.55
3	12.90	7.34	31.94	6.25	12.99	46.67

The following observations are made from these graphs:

(i)   In general, percentage shortage is almost double for reservation holding period as 3 days as compared to the same as 1 day for both single and double cross matching strategies. In single cross matching strategy the percentage shortages were 14.92 and 6.45 for reservation holding periods as 3 days and 1 day respectively. In double cross matching strategy, the minimum shortages occurred for minimum pair age difference of 13 days and 7 days for reservation holding period as 3 days and 1 day respectively. The corresponding values for shortage were 8.06% and 4.03%.

(ii)   In most of the cases, the double cross matching strategy resulted in less shortage (in percentage) as compared to the single cross matching strategy.

(iii) For both the strategies, in general, percentage wastage are almost double for reservation holding period of 1 day as compared to same of 3 days. In double cross matching the minimum percentage wastages were 4.24 and 12.15 corresponding to reservation holding periods as 3 days and 1 day.

(iv)   For both the strategies, the percentage increase in utilization efficiency is more for reservation holding period as 1 day compared to the same as 3 days.

(v)   For reservation holding period as 3 days the percentage increase in utilization efficiency is more for the double cross matching compared to the single cross-matching. However, the
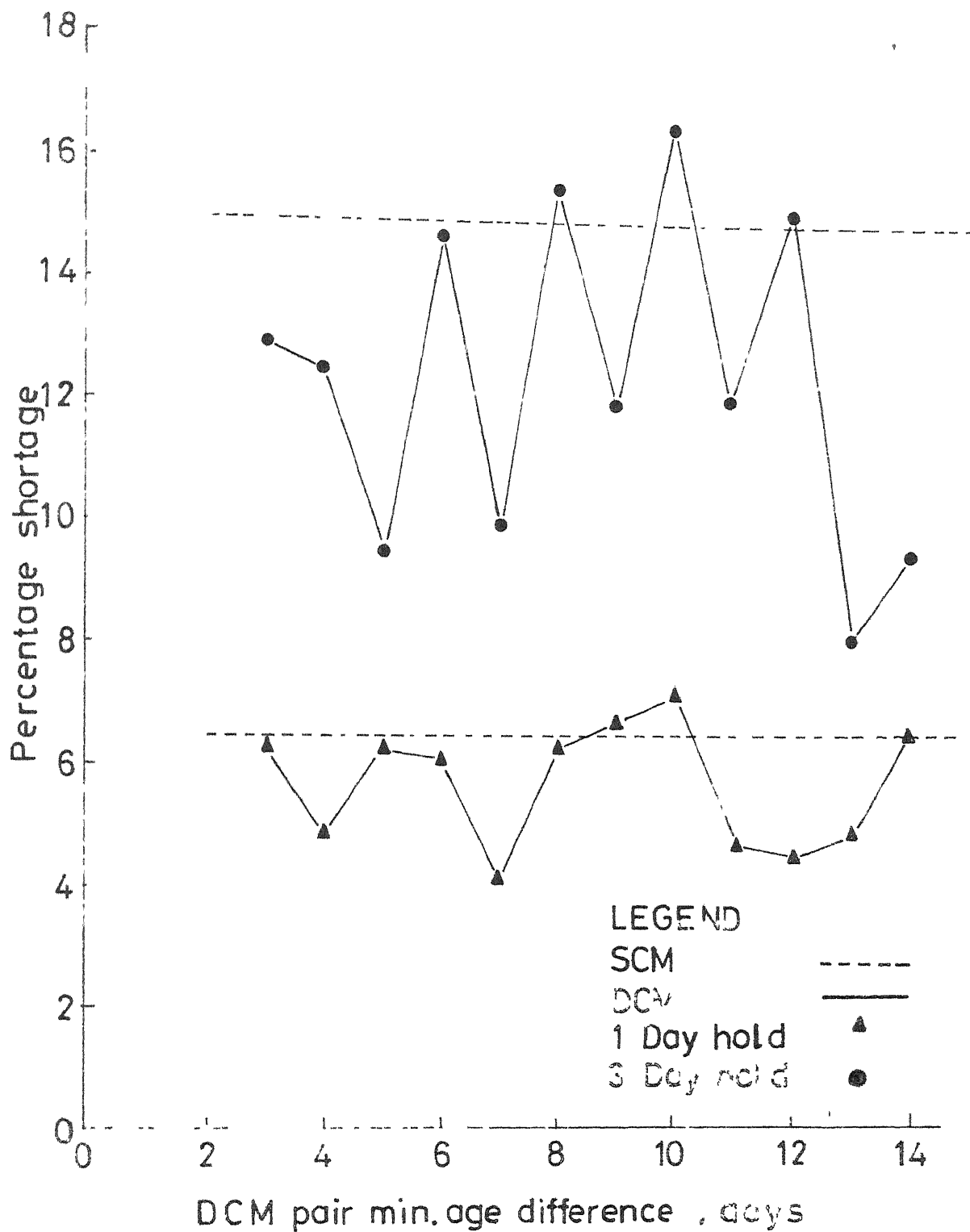
Fig. 4·3 Comparison of percentage shortage for SCM & DCM (Case study)
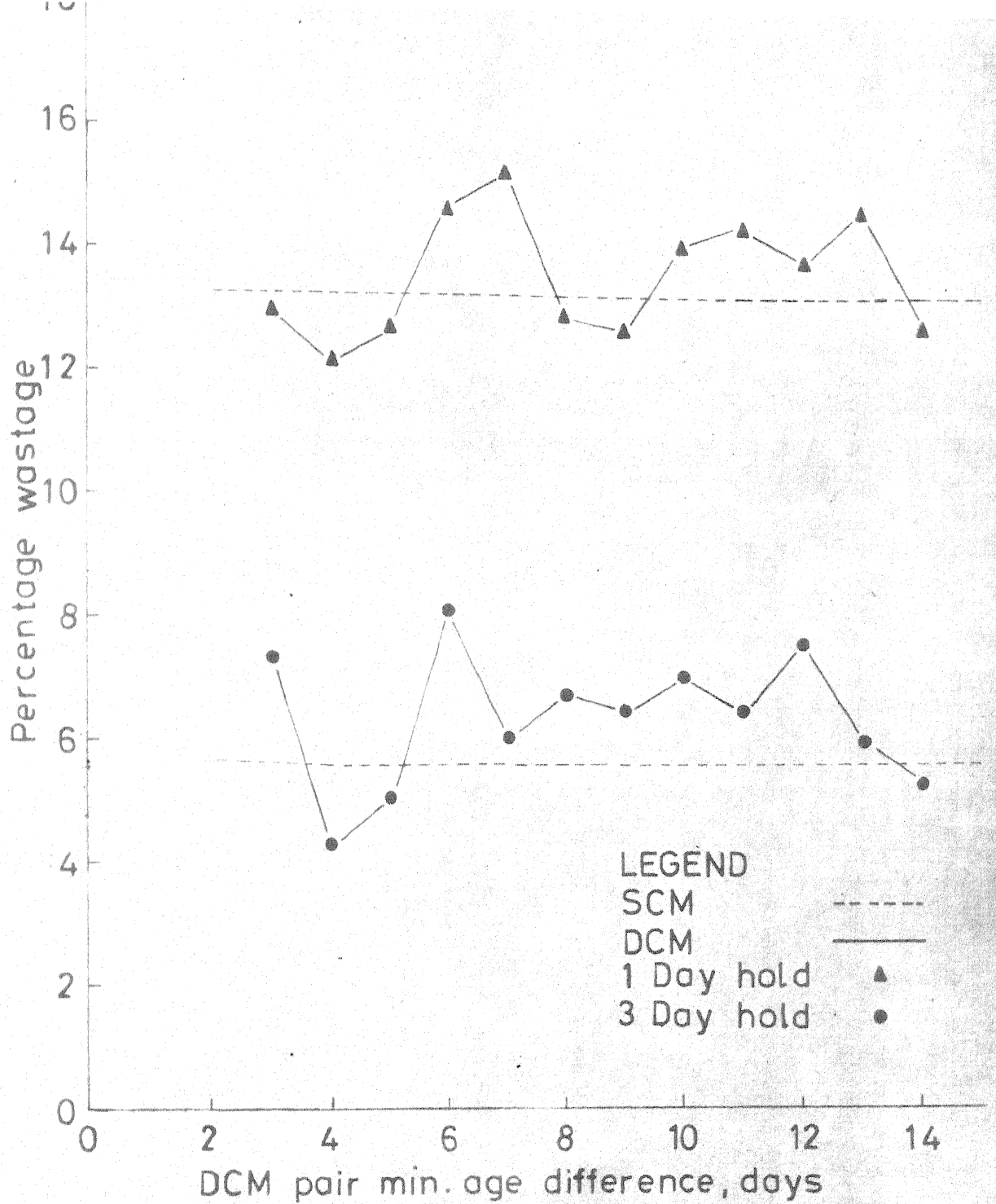
Fig. 4·4 Comparison of percentage wastage for SCM & DCM (Case study)
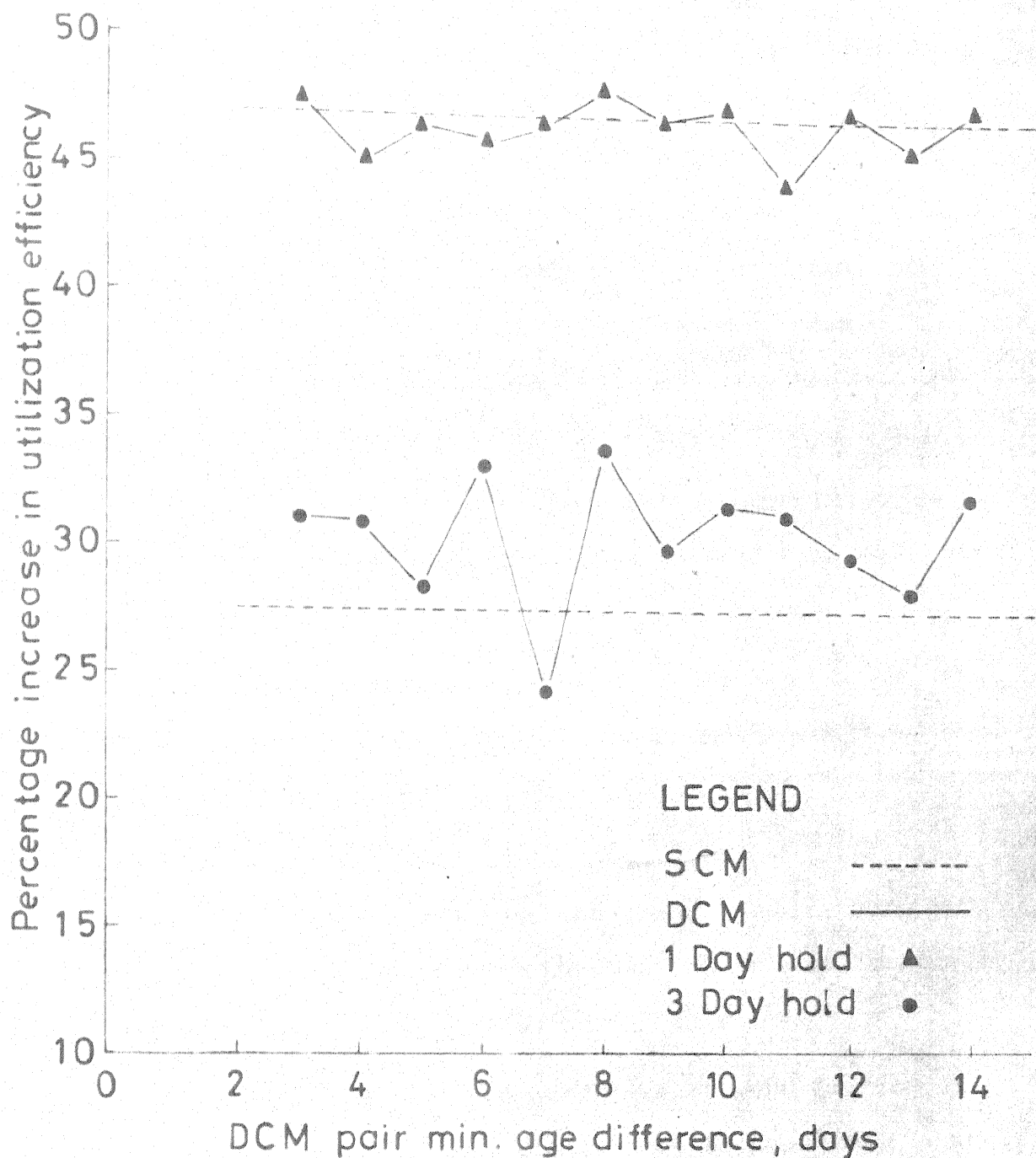
Fig. 4·5 Comparison of increase in utilization efficiency for SCM & DCM (Case study)

percentage utilization efficiency for reservation holding period as 1 day is more in the case of single cross matching compared to double cross matching.

The results of the case study suggest the following.

(1)   If shortage used as criterion, the double cross matching strategy should be adopted with DCM pair minimum age difference as 7 days and reservation holding period as 1 day.

(2)   If wastage is to be used as criterion, adoption of single cross matching strategy is recommended with reservation holding period as 3 days.

(3)   If the increase in utilization efficiency is to be used as criterion, the single cross match strategy should be adopted using 1 day holding period for reservation.

(4)   Considering shortage, wastage and increase in utilization efficiency equally important the use of double cross match ing strategy is suggested with pair minimum age difference as 4 days and reservation holding period as 1 day.

In both the case of generated data as well as case study   the wastage reduction could not be achieved due to less number of actual call for younger paired units,which first of all depend on the number of double cross matched pairs formed.

4.3 COMPARISON OF COMPUTATIONAL TIMES:

The execution time requirements for single cross
matching and double cross matching strategies using generated
and case study data are listed in Table 4.5. The execution
time requirements are based on twelve simulation runs each
for the cases of reservation holding period as 1 day and 3 days.

Table 4.5· Execution times for twelve simulation runs.

Data	Reservation holding period (Days)	Time in Seconds		Percentage increase from SCM
		SCM	DCM	
Generated	1	20	22	10
	3	22	28	27.2
Case study	1	14	16	14.3
	3	18	23	21.7

On the basis of above table it is observed that for the
generated data as well as the case study the execution times
for 3 days holding period for reservation were more compared
to the reservation holding period as 1 day irrespective of
the strategy adopted. Further as has already been pointed out,
the percentage wastage is less when 3 days holding period for
reservation is used, slight increase in computer time can be
justified.

As expected, in all situation the double cross matching strategy takes more time compared to single cross matching strategy.

4.4 CONCLUSIONS:

The results based on the generated data and case study indicate that in most of the cases the performance of double cross matching strategy is slightly better than single cross matching in terms of higher percentage utilization efficiency and lower shortage. However, it was observed that for both the generated data and the case study, the blood wastages were some what higher for most of the DCM pair minimum age differences considered as compared to the single cross matching strategy.

Based on the study, the adoption of double cross matching strategy is recommended for Regional Blood Centres.

4.5 SCOPE FOR FUTURE WORK:

Whenever we move in some direction for the fulfilment of certain objectives, even after getting the same, it is usually observed that new horizons emerge towards which further effort may be directed. Present work also could not escape the similar happening and as such the future work may be taken up in the following directions.

i)   As mentioned in Section 3.3.2, in the present work
only two holding periods for reservations viz., 1 day and
3 days were considered. However, it would be worthwhile to
study the influence of other values of reservation holding
periods on wastage, shortage and increase in utilization
efficiency with a view to determine optimal value of reser-
vation holding period.

ii)   In the present work, the double cross match pair forma
tion was done using minimum age difference among paired units
as criterion. An alternative strategy for pair formation could
be to form pairs out of a fixed percentage of older and younger
units among singly reserved units. The performance of such a
strategy needs to be evaluated.

iii)   Extending the basic concept of double cross matching,
one may evolve a multiple cross matching policy. In the
multiple cross matching strategy, each cross matched unit of
the multiplet will be reserved in the name of more than two
patients and in the event of calls, older units would be
issued to the patients in order of their call for the unit.
It is possible that the multiple cross matching strategy will
further significantly reduce the wastage but this may involve
considerably more number of cross matches to be performed along
with computational and book keeping effort.

iv)   The present work is confined to the management of blood
for a regional blood centre. However, it would be desirable
to develope computer oriented integrated systems for the
management of blood at the state level (comprising of many
regional blood centres) and then for the country as a whole
in order to use this scarce, life saving, perishable commodity
in the most efficient way.

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```
$JCB    MEG371,TIMECCR,PAGISCIO,NAME, SHEKHAR
$IBJCB
$IEFTC MAIN
C
C
C                          APPENDIX..I
C
C
C       **************************************************************
C       **************************************************************
C       CN  SAIRAM
C       EVALUATICN CF STRATEGIES FCR THE MANAGEMENT CFREGIONAL BLCCD CENTRE
C       CCMPLTER PACKAGE   WITH  3  DAYS  RESERVATION  HCLDING  PERICD
C             BY
C       ----------------------------------------------------------------
C       **************************************************************
        INTEGER  TPC,TAP,TSHRTG,TCALL,TUNCAL,TCNUSE,TBDAP
        INTEGER  CN,CPN,CBN,PEN,PBN,PBN,ABN,CCLECT,RNI
        INTEGER  TBSA,TPSA,TCLECT,CEN,CBH
        INTEGER  UNASNC,ASINC,COATS,TUNCGW,TCNUGW,TAGW
        INTEGER  PRCCLF(   ),IST(2)
        INTEGER  BATAKE( ),DEMANC(  ),NUCALD(6C)
        INTEGER  CBNA(60),CBNE(6J),CBNC(60)
        INTEGER  RETBNA(  ),PECMPN(  )
        INTEGER  CBARAY(  ),PEARAY(   )
        INTEGER  MM(9CC, ),ASINEC(7CC, ),DM(5C,5)
        INTEGER  AX,AY,AV,AW,AZ
        CCMMCN /A/  AX,AY,AV,AW,AZ
C       **************************************************************
  101 FCRMAT(2CI4)
  102 FCRMAT(15X,21I3)
  105 FCRMAT(15X,*-------------------------------- DAY  NO...*,I4)
  108 FCRMAT(1H1,14X,*RESULTS WITH SINGLE CRCSS MATCH, 3 DAY HCLD*,//)
  109 FCRMAT(///,14X,*RESULTS WITH DCUBLE CRCSS MATCH,3 DAY HCLD*,//)
  110 FCRMAT(5X,3CI4)
  115 FCRMAT(15X,1CI6)
  116 FCRMAT(1H ,14X,8F6.2,2F7.0,F6.3)
  120 FCRMAT(15X,*NO RETURN  OF  CALLED BLOCD  CN  DAY  NO....*,I4)
  121 FCRMAT(15X,*NC  BOTTLE  CALLED  CN  DAY  NO.....*,I4)
  122 FCRMAT(15X,*NC  CUBLE  CRCSS  MATCH  ON  DAY  NC....*,8I4)
C       ----------------------------------------------------------------
C       XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
C       **** DESCRIPTICN CF VARIABLES LSED ****
C       XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
C       CN    ...DAY NUMBER CF A SIMULATION RUN.
C       PBN   ...PERMANENT BOTTLE SEQUENCE NUMBER LABELED BY THE CENTRE
C       CCLECT...CCLECTICN OF FRESH UNITS CN A CAY BY THE CENTRE
C       TED   ...TCTAL NUMBER CF BOTTLES DEMANDED FROM THE CENTRE
C       TAP   ...TCTAL NUMBER OF PATIENTS FCR WHOM RESERVATION REQUESTS CAME
C       TSCRTG...TCTAL NUMBER OF SHCRTAGES OF UNITS AT THE CENTRE
C       TCALL ...TCTAL NUMBER CF UNITS CALLED FRCM THE CENTRE
C       TUNCAL...TCTAL NUMBER CF UNITS NOT CALLED FRCM THE CENTRE
C       TCNUSE...TCTAL NUMBER CF UNITS CALLED BUT NOT USED BY THE HOSPITALS
C       TBDAP ...TCTAL NUMBER CF BOTTLE DOUBLY ASSIGNED PAIRS MADE AT THE CENTRE
C       TCLECT...TCTAL NUMBER CF UNITS COLLECTED BY THE CENTRE
C       TBSA  ...TCTAL NUMBER CF BOTTLES SINGLY ASSIGNED BY THE CENTRE
```

```
C       TFSA   ...TOTAL NUMBER OF PATIENTS  SINGLY ASSIGNED BY THE CENTRE
C       TUNCCW...TOTAL NUMBER OF UNITS NOT CALLED AND ARE GOING WASTE
C       TCNUGW...TOTAL NUMBER OF CALLED UNITS NOT USED AND ARE GOING WASTE
C       TAGW   ...TOTAL NUMBER OF UNITS ACTUALLY GOING WASTE DUE TO AGING ONLY
C       UNASAC...TOTAL NUMBER OF UNASSIGNED UNITS AVAILABLE AT THE CENTRE
C       ASIAD ...MINIMUM NUMBER OF UNITS ASSIGNED FOR REQUESTS MET BEFORE
C       CCATE ...TOTAL NUMBER OF UNITS OUTDATED IN THE SYSTEM
C       NOPR  ...NUMBER OF PATIENTS REQUESTING FOR RESERVATION ON A DAY
C       NCBC  ...NUMBER OF BOTTLES CALLED ON A DAY BY THE HOSPITALS
C       NCBR  ...NUMBER OF BOTTLES RETURNED ON A DAY BY THE HOSPITALS
C       ****************************************************************
C       ----------------------------------------------------------------
C       ****************************************************************
        PRINT 119
        NROONS=1
        CALL TIME(NOW)
        IXX=0
123     CONTINUE
        SIMNC=13.
        SIMNC=1.
        ACCCCN=14
124     CONTINUE
        NNN=1
        CALL INRANC(NNN)
        DO 125 I=1,21
        PROCUR(I)=0
125     IST(I)=0
        DO 135 I=1,50
        CM(I,1)=-1
        CM(I,2)=-1
        CM(I,3)=-1
        CM(I,4)=-1
135     CM(I,5)=-1
        DO 145 I=1,60
        NUCALC(I)=-1
        IF(SIMNC.GT.24.)INTAKE(I)=-1
        DEMAND(I)=-1
        CBNA(I)=-1
        CBNE(I)=-1
        CBNC(I)=-1
        RCOMEN(I)=-1
145     RETENA(I)=-1
        DO 150 I=1,250
        REARAY(I)=-1
150     CBARAY(I)=-1
        DO 155 I=1,700
        ASINEC(I,1)=-1
        ASINEC(I,2)=-1
155     ASINEC(I,3)=-1
        DO 165 I=1,900
        MM(I,1)=-1
        MM(I,2)=-1
        MM(I,3)=-1
        MM(I,4)=-1
165     MM(I,5)=-1
        TBD=0
```

```
      TNP=C
      TSCRTG=0
      TCALL=C
      TUNCAL=0
      TCNUSE=0
      TBCAP=0
      TCLECT=0
      ASINC=0
      CCATE=0
      TUNCGW=0
      TCNUGW=C
      TAGW=0
      KZ=C
      UNASNC=0
      TESA=0
      NN=C
      LF=C
      LC=C
      LX=0
      INCCN=0
      LA=0
      FPN=1
      AEN=1
      CN=1
      N4=C
      NTLW=0
      LSP=0
      RETENA(4)=0
C     ***********************************************************************
C     INITIAL  STCCKING
C     ***********************************************************************
C     FRINT 105,CN
      IF(INCCN.EC.(-1)) GO TO 250
      CC 175 I=18,21
  175 IST(I)=C
      CC 195 L=1,17
      K=18-L
      IST(K)=RANCYX(AX)*4.
      IN=IST(K)
      IF(IN.EC.C)  GC TC 195
      N3=N4+1
      N4=N4+IN
      CC 185 I=N3,N4
      PEN=I
      NN(PEN,1)=1
      NN(FEN,2)=K
      NN(PEN,3)=0
  185 CCNTINUE
  195 CCNTINUE
C     FRINT 102,(IST(I),I=1,21)
      INCCN=-1
      UNASNC=UNASNC+N4
      K4=N4
C     ---------------------------------------7--------------------------
C     ***********************************************************************
C     FRCCUREMENT
```

```
C     ***********************************************************************
C     ------------------------------------------------------------
      IF(IXX.NE.0)  GC TO 250
      IF(SIMNC.NE.1.)  GC TC 250
      READ  101,(INTAKE(I),I=1,30)
250   CCNTINUE
      IND=CN-CN/3*3
      IF(IND.EC.0) IND=3
      CCLECT=RNDYX(AX)+51.
      IF(IXX.NE.0)  GC TC 255
      IF(SIMNC.EC.13.) INTAKE(CN)=CCLECT
255   CCNTINUE
      IF(SIMNC.LE.24.) CCLECT=INTAKE(CN)
      IF(CCLECT.EC.0)CCLECT=1
      PRCCUR(1)=CCLECT
      INTAKE(CN)=CCLECT
C     ***********************************************************************
C     STOCK  ENTRY
      K3=K4+1
      K4=K4+CCLECT
      CC 265 I=K3,K4
      PEN=I
      MM(I,1)=I
      MM(I,2)=1
      MM(I,3)=0
265   CCNTINUE
280   TCLECT=K4
      UNASAD=UNASAD+COLECT
C     ***********************************************************************
C
C     ------------------------------------------------------------
C     RETURN  CF  UNUSED  CALLED  BOTTLES
C     ------------------------------------------------------------
C     ***********************************************************************
      LKR=5
      JX=6
      JY=6
      IF(CN.LE.4)  GC TC 399
      BR=AUCALC(CN-3)
      NCBR=RNDYV(AV)*BR
      LX=NCBR
      LY=0
      IF(LX.EC.0)  GC TC 390
      IF(IND.EC.1)  GC TC 320
      IF(IND.EC.2)  GC TC 350
      LY=CENC(3)-5
      IF(LY.LE.0)  GC TC 390
      IF(LX.GT.LY)LX=LY
      CC 320 JU=1,LX
      RBN=CBNC(JU+5)
      MM(RBN,3)=0
      MM(RBN,4)=0
      IF(MM(RBN,2).LE.17)  GC TO 215
      MM(RBN,5)=0
      TCNUGW=TCNUGW+1
      CDATE=CDATE+1
      GC TC 320
```

```
315 UNASNC=UNASNC+1
    MM(REN,5)=-2
    RETENA(JX)=REN
    JX=JX+1
320 CCNTINUE
    GC TC 397
330 LY=CENA(3)-5
    IF(LY.LE.0)  CC TC 390
    IF(LX.GT.LY)LX=LY
    CC 340  JV=1,LX
    REN=CBNA(JV+5)
    MM(REN,2)=0
    MM(REN,4)=0
    IF(MM(REN,2).LE..1)  CC TC 335
    MM(REN,5)=0
    TCNUGW=TCNUGW+1
    CCATE=CCATE+1
    GC TC 340
335 UNASNC=UNASNC+1
    MM(REN,5)=-2
    RETENA(JX)=REN
    JX=JX+1
340 CCNTINUE
    GC TC 397
350 LY=CBNB(3)-5
    IF(LY.LE.0)  GC TO 390
    IF(LX.GT.LY)LX=LY
    CC 360  JW=1,LX
    REN=CBNB(JW+5)
    MM(REN,3)=0
    MM(REN,4)=0
    IF(MM(REN,2).LE.17)  GO TO 355
    MM(REN,5)=0
    TCNUGW=TCNUGW+1
    CCATE=OCATE+1
    GC TC 360
355 UNASNC=UNASNC+1
    MM(REN,5)=-2
    RETBNA(JX)=REN
    JX=JX+1
360 CCNTINUE
    GC TC 397
390 CCNTINUE
C   PRINT 120,CN
    IF(LY.LE.0)  GC TC 398
397 TCNUSE=TCNUSE+LX
398 RETENA(3)=JX-1
    RETENA(1)=CN
    RETENA(4)=3
    LKR=RETBNA(3)
399 CCNTINUE
C   ****************************************************************
C   ----------------------------------------------------------------
C   CALL  OF  BCTTLES
C   ----------------------------------------------------------------
C   ****************************************************************
```

```
      LTR=SCO
      IF(CN.EC.1)   GC TC 49C
      IF(CN.GT.4)   GC TC 412
      IF(CN.GT.2)   GC TC 41?
      CC 401 I=1,M3
401   CBARAY(I)=RBARAY(I)
      GC TC 415
402   IF(CN.GT.2)   GC TC 405
      J12=L2-L1
      CC 404 I=1,J12
      MI=M1+I
      LI=L1+I
404   CBARAY(MI)=RBARAY(LI)
      M3=MI
      GC TC 415
405   J23=L3-L2
      DC 408 I=1,J23
      MI=M2+I
      LI=L2+I
408   CBARAY(MI)=RBARAY(LI)
      M3=MI
      GC TC 415
412   IH=M3-M1
      IF(M3.FC.M1)   GO TC 4130
      CC 413 I=1,IH
      IL=I+M1
413   CBARAY(I)=CBARAY(IL)
      M1=M2-M1
      M2=IH
      GC TC 4131
4130  M1=0
      M2=C
      IH=0
4131  CCNTINUE
      IJ=L3-L2
      CC 414 I=1,IJ
      IM=IH+I
      IMM=L2+I
414   CBARAY(IM)=RBARAY(IMM)
      M3=IM
415   NCBC=1.+RNCYZ(AZ)*50.
      LC=NCBC
      LD=M3
      IF(LC.LE.3)   GC TC 490
      IF(LC.GE.LD)   GC TC 415
      LK=5
      LKK=LC+5
      CC 480 JJ=1,LC
      A3=M3
416   CBH=1.+RNCYW(AW)*A3
      CBN=CBARAY(CBH)
      LHH=MM(CBN,5)
      IF(LHH.EQ.2)   CO TC 425
      IF(LHH.NE.1)   CO TC 479
417   CCNTINUE
      IF(CBH.NE.M3)   GC TC 419
```

```
      IF(M1.EC.M3)M1=M1-1
      IF(CN.LE.2)  GC TC 418
      IF(M2.EC.M3)M2=M2-1
418   M3=M3-1
      A3=M3
      GC TC 450
419   IF(CEH.GT.M1)  GC TO 421
      M1=M1-1
      IF(CN.LE.2)  GC TO 423
421   IF(CEH.GT.M2)  GC TO 423
      M2=M2-1
423   M3=M3-1
      A3=M3
      CC 424 I=CEH,M3
      IK=I+1
424   CEARAY(I)=CEARAY(IK)
      GC TC 450
425   KAS=ASINED(CEN,3)
      IF(MM(KAS,5).EC.3)  GC TC 417
      ASINED(CEN,3)=C
      ASINED(KAS,3)=0
      MM(CEN,4)=-2
      MM(KAS,4)=-2
      IF(CEN.LT.KAS)  GC TC 430
      IF(CEN.LT.LTR)LTR=CEN
      MM(CBN,5)=1
      CC 427 IK=1,M3
      KASN=CBARAY(IK)
      IF(KAS.NE.KASN)  GC TC 427
      CEH=IK
      CBN=KAS
      GC TC 417
427   CCNTINUE
430   MM(KAS,5)=1
      GC TC 417
450   MM(CBN,5)=3
455   LK=LK+1
      IF(INC.EC.1)  GO TO 460
      IF(INC.EC.2)  GO TO 470
      CBNC(LK)=CEN
      IF(LK.LT.LKK) GC TO 480
      CENC(1)=CN
      CBNC(2)=INC
      CENC(3)=LKK
      GC TC 495
460   CENA(LK)=CBN
      IF(LK.LT.LKK)  GC TO 480
      CBNA(1)=CN
      CBNA(2)=INC
      CBNA(3)=LKK
      GC TC 495
470   CBNE(LK)=CBN
      IF(LK.LT.LKK)  GC TO 480
      CBNE(1)=CN
      CBNE(2)=INC
      CBNE(3)=LKK
```

```
      GC TC 495
  479 LAB=LC-JJ
      IF(LAB.GT.7)  GO TO 416
      GC TC 494
  480 CCNTINUE
  490 CCNTINUE
C     PRINT  321,CN
      GC TC 495
  494 LC=JJ-1
  495 CCNTINUE
      TCALL=TCALL+LC
      NUCALC(CN)=LC
C     ***********************************************************
C     -----------------------------------------------------------
C     CANCELATICN  CF  RESERVATION
C     -----------------------------------------------------------
C     ***********************************************************
      IF(CN.LE.3)  GC TC 599
      CC 590 I=1,L1
      LP=REARAY(I)
      IF(LF.EC.0)  GC TC 590
      LS=MM(LF,5)
      IF(LS.EC.3)  GC TC 590
      IF(LS.EC.0)  GC TC 590
      IF(MM(LP,2).LE.17)  GC TO 520
      IF(LS.NE.2)  GC TO 515
      LPM=ASINED(LP,3)
      IF(LPM.LE.0)  GC TO 515
      MM(LPM,5)=1
      ASINED(LPM,3)=-2
      ASINED(LP,3)=-2
  515 CCNTINUE
      MM(LF,5)=0
      TUNCGW=TUNCGW+1
      CDATE=CDATE+1
      GC TC 590
  520 IF(LS.NE.1)  GC TO 540
      RETENA(JX)=LP
      MM(LF,3)=0
      MM(LF,5)=-2
      GC TC 580
  540 IF(LS.NE.2)  GC TO 550
      LPA=ASINED(LF,3)
      IF(MM(LPA,5).LE.0)  GO TO 550
      MM(LF,3)=MM(LF,4)
      MM(LF,4)=-2
      MM(LF,5)=1
      RCCMEN(JY)=LF
      JY=JY+1
      GC TC 560
  550 LPA=LF
  560 CCNTINUE
      RETENA(JX)=LPA
      MM(LPA,3)=0
      MM(LPA,4)=-2
      MM(LPA,5)=-2
```

```
      ASINED(LPA,2)=-2
      ASINED(LPA,3)=-2
      ASINED(LP,2)=LPA
      ASINED(LP,3)=-2
  580 TUNCAL=TUNCAL+2
      UNASND=UNASND+1
      JX=JX+1
  590 CONTINUE
      RETENA(1)=ON
      RETENA(4)=5
      RETENA(3)=JX-1
      LKR=RETENA(3)
      RECNEN(1)=ON
      RECNEN(4)=7
      RECNEN(3)=JY-1
      LKS=RECNEN(3)
  599 CONTINUE
C     ********************************************************************
C     --------------------------------------------------------------------
C     RESERVATION
C     --------------------------------------------------------------------
C     ********************************************************************
      IF(EN.NE.1)  GC TO 606
      A2=0
      K2=0
  606 CONTINUE
      NCPR=1.+RNCYX(AX)*13.
       TNP=TNP+NCPR
      ARR=C
      NPT=0
      IF(EN.LE.3)  GC TO 630
      L12=L2-L1
      CC 615 I=1,L12
      IA=I+L1
  615 REARAY(I)=RBARAY(IA)
      L21=L12+1
      L23=L3-L1
      CC 625 I=L21,L23
      IB=I+L1
  625 RBARAY(I)=REARAY(IB)
      L1=L12
      L2=L23
      KTR=L2+1
  630 A1=A2+1
      A2=A2+NCPR
      NRC=C
      KZ=5
      CC 660 J=N1,N2
      NRD=NRC+1
      CPN=NRC
      FPN=J
      RA=1.+RNCYY(AY)*4.
      NEREP=RN
      K1=K2+1
      K2=K2+NEREP
      DC 670 KK=K1,K2
```

```
      NRR=NRR+1
      CEN=KK
      CM(NRR,1)=NRE
      CM(NRR,2)=NRR
      TEC=TEC+1
      IF(UNASNC.GT.C) GC TC 650
      NFT=1
      CM(NRR,3)=0
      CM(NRR,4)=0
      CM(NRR,5)=C
      NRRSFC=NRR-1
      TSCRTG=TSCRTC+1
      GC TC 670
  650 INDEX=1
      IF(CN.LE.3) GC TC 663
      KRP=5
      KN=PETBNA(3)
      IF(KN.LT.6) GC TC 661
      NA=KZ+1
      IF(NA.GT.KN) GC TC 661
      IF(KZ.GT.KM) GC TC 661
      DC 656 KR=NA,KM
      KN=PETBNA(KR)
      KZ=KZ+1
      ABN=KN
      INDEX=0
      KRP=KR
      ASINED(ABN,1)=J
      ASINED(ABN,2)=ABN
      GC TC 669
  656 CCNTINUE
  661 ABN=ASINC+1
  662 ASINED(CBN,2)=ABN
      ASINED(CBN,1)=J
  663 LNASNC=UNASNC-1
      CM(NRR,3)=J
      CM(NRR,4)=AEN
      CM(NRR,5)=1
      MM(ABN,5)=1
      MM(AEN,3)=J
      TBSA=TBSA+1
      TPSA=J
      IF(CN.GT.3) GC TC 665
      REARAY(TBSA)=ABN
      GC TC 669
  665 REARAY(KTR)=ABN
      KTR=KTR+1
  669 CCNTINUE
      IF(INDEX.EQ.0) GC TC 670
      ABN=ABN+1
      ASINC=ASINC+1
  670 CCNTINUE
  680 CCNTINUE
      IF(CN.GT.3)L3=KTR-1
  685 CEMANC(CN)=NFR
      IF(NFT.EC.0)NRRSPC=NRR
```

```
      IF(LN.GT.2)  GC TC 691
      L3=TESA
      M3=L3
      IF(LN.NE.1)  GC TC 686
      L1=TESA
      M1=L1
      GC TC 691
686   IF(LN.NE.2)  GC TC 688
      L2=TESA
      M2=M1+L2-L1
688   M3=M2+L3-L?
691   CCNTINUE
      IF(LNASNE.LT.0)UNASNE=0
      IF(LN.LE.3)  GC TC 695
       IF(KM.LE.KRP)  GC TC 695
      LW=KM-KRP
      ATLW=ATLW+LW
      UNASNC=UNASNC-LW
      IF(LNASNC.LT.0)UNASNC=0
695   CCNTINUE
      IF(NFCCMS.EC.1)  GC TC 789
C     ***************************************************************
C     ---------------------------------------------------------------
C     DCUBLE  CRCSS  MATCHING
C     ---------------------------------------------------------------
C     ***************************************************************
721   NS=TECAP+1
      KX=0
      N6=TECAF+(ASINC-TECAP)/2
722   LR=NE
      IF(N6.LE.N5)  GO TO 788
      KLL=6
      KP=RCCMEN(3)
      CC 767 NN=NS,NE
      NR1=NN
      IF(LN.LE.3)  GC TO 745
      IF(KP.LT.6)  GC TO 745
      IF(KLL.GT.KP)  GC TO 745
      NR1=RCCMEN(KLL)
      KLL=KLL+1
745   IF(MM(NR1,5).EC.1)  GC TC 753
      NR1=NR1+1
      IF(NR1.GT.ASINC)  CO TC 788
      GC TC 745
752   AR=MM(NR1,2)
      JS=MM(NR1,5)
763   AR3=MM(LR,2)
      JR=MM(LR,5)
      JC=AR-NR3
      IF(JC.LT.NCCCCM)  CO TC 766
      IF(JS.NE.1)  GC TC 767
      IF(JR.NE.1)  GC TC 766
764   NP1=AR3
      KT=LR-1
      NP2=MM(KT,2)
      IF(NP1.NE.NP2)  GC TC 765
```

```
      AF3=MM(KT,5)
      IF(AF3.EG.2)  GC TC 765
      LR=LR-1
      GC TC 764
  765 AR2=LR
      MM(AR1,4)=MM(NR2,3)
      MM(AR2,4)=MM(NF1,3)
      MM(AR1,5)=2
      MM(AR2,5)=2
      ASINEC(AR1,3)=AR
      ASINEC(AR2,3)=AR
      LR=LR+1
      TECAP=TECAP+1
      KX=KX+1
      GC TC 767
  766 LR1=LR+1
      LR=LR1
      IF(LR.GT.ASINC)  GC TC 788
      GC TC 763
  767 CCNTINUE
  788 IF(KX.NE.0)  GC TC 789
      AN=1000
C     PRINT  122,CN,A9,K6,LR,ASINC,TECAP,TPSA,AN
  789 CONTINUE
C     ***********************************************************
C     -----------------------------------------------------------
C     UPCATING  ANC  STATISTICS
C     -----------------------------------------------------------
C     ***********************************************************
C     .........................................................
C     WASTE  CALCULATION
C     .........................................................
      MA=LA
      DC 810 IA=1,TCLECT
      KA=MM(IA,2)
      IF(KA.LT.18)  GO TC 820
      KB=MM(IA,5)
      IF(KE.GE.0)  GC TC 805
      COATE=COATE+1
      UNASAC=UNASNC-1
      IF(UNASAC.LT.0) UNASNC=0
      TAGW=TAGW+1
      MM(IA,5)=0
  805 LA=LA+1
  810 CCNTINUE
  820 CCNTINUE
      IF(TCLECT.GT.900)  GC TO 599
C     ...................................................
C     AGE  UPCATING
C     ...................................................
      DC 835 I=1,TCLECT
  835 MM(I,2)=MM(I,2)+1
C     ...................................................
C     STATISTICS  PRINTING
C     ...................................................
      LSP=LSP+UNASAC
```

```
      AVINVP=LSF/CN
C     PRINT  110,CN,COLECT,TCLECT,TNP,NRR,TEC,TBSA,ASIND,TUNCAL,TPCAP,TS
C    1CRTG,TCALL,TCNUSE,CDATE,TUNCCW,TCNUGW,TAGW,LX,NTLW,UNASND
      CN=CN+1
      IF(CN.LE.30)  GO TO 250
C     PRINT  110,(CEMANC(I),I=1,30)
C     PRINT  110,(INTAKE(I),I=1,30)
C     PRINT  110,(NUCALE(I),I=1,30)
      AWASTE=CCATE
      AVECFP=TEC/TNP
      SCRTP=FLCAT(TSCRIG)/FLCAT(TEC)*100.
      WASTEC=AWASTE/FLCAT(TEC)*10C.
      WASTFC=AWASTE/FLCAT(TCLECT)*100.
      CALLP=FLCAT(TCALL)/FLCAT(TBSA)*1000.
      UNCALP=FLCAT(TCNUSE)/FLCAT(TCALL)*100.
      UNRESP=FLCAT(TUNCAL)/FLCAT(TBSA)*100.
      UEFFIN=(FLCAT(TBSA)-FLCAT(ASIND))/FLCAT(TBSA)*100.
      PRINT  115,SIMNC,AVBEFP,SCRTP,WASTEC,WASTFC,CALLP,UNCALP,UNRESP,AV
     1INVF,AWASTE,UEFFIN
      SIMNC=SIMNC+1.
      NCCCCN=NCDCCN-I
      IF(NCCDCM.GE.3)   GC TC 124
      NFDCNS=NFDCMS+1
      IXX=IXX+I
      IF(NFDCMS.EC.2)PRINT  109
      IF(NFDCMS.EC.2)  GO TO 123
  999 STCP
      END
C     **********************************************************************
C     **********************************************************************
$IBFTC RNCYX
      FUNCTION  RNCYX(XX)
      INTEGER  A,XX
      CATA  A/186277/
      XX=A*XX
      AY=XX
      RNCYX=AY/34359738638.
      RETURN
      END
$IBFTC RNCYY
      FUNCTION  RNCYY(YY)
      INTEGER  B,YY
      CATA  B/186285/
      YY=B*YY
      BY=YY
      RNCYY=BY/34359738638.
      RETURN
      END
$IBFTC RNCYV
      FUNCTION  RNCYV(VV)
      INTEGER  C,VV
      CATA  C/186293/
      VV=C*VV
      CY=VV
      RNCYV=CY/34359738638.
      RETURN
```

```
        END
$IBFTC RNDYW
        FUNCTION  RNDYW(WW)
        INTEGER   C,WW
        DATA  C/186301/
        WW=C*WW
        DY=WW
        RNDYW=DY/34359738638
        RETURN
        END
$IBFTC RNDYZ
        FUNCTION  RNDYZ(ZZ)
        INTEGER   E,ZZ
        DATA  E/186350/
        ZZ=E*ZZ
        EY=ZZ
        RNDYZ=EY/34359738638.
        RETURN
        END
$IBFTC INRAND
        SUBROUTINE  INRAND(NNN)
        INTEGER   AX,AY,AV,AW,AZ
        COMMON  /A/   AX,AY,AV,AW,AZ
        IF(NNN.EQ.1)  GC TC 5C
        GC TC 60
   50  AX=11750920161
        AY=27594084237
        AV=10796931217
        AW=17669802561
        AZ=560227513
   60  RN1=RNDYX(AX)
   60  RN1=RNDYX(AX)
        RN2=RNDYY(AY)
        RN3=RNDYV(AV)
        RN4=RNDYW(AW)
        RN5=RNDYZ(AZ)
        NNN=NNN+1
        RETURN
        END
$ENTRY
```

```
$JCB    MEG371,TIMECC8,PAGESCIC,NAME   SHEKHAR   611403
C
C
C                              APPENDIX..II
C
C
C
C    -----------------------------------------------------------------
C    CN SAIRAM
C    EVALUATION CF STRATEGIES FOR THE MANAGEMENT OFREGICNAL BLCCC CENTRE
C    CCMFLTER PACKAGE   WITH   1 CAY  RESERVATION  HOLDING   PERICD
C    -----------------------------------------------------------------
      INTEGER   CREN(60)
      DIMENSICN  NLCALC(60)
      INTEGER   UNASNC,ASINC,CDATE,ILACGW,TCALCW,TAGW
      INTEGER   INTAKE(60),DEMANC(50)
      INTEGER   TCLECT
      INTEGER   RAEN(60),RDCMBN(60)
C     **************************************************************
      INTEGER   CN,CPA,CEN,FFN,PBN,FBN,ASN,CCLECT,RN1
      INTEGER   TESA,TPSA,TST,TWASTE
      INTEGER   TBC,TAP,TSORTG,TCALL,TUNCAL,TCNUSE,TBCAP
      INTEGER   PRCCUR(21),IST(21)
      INTEGER   MM(900,5),ASINEC(700,3),DM(50,5)
      INTEGER   CBAA(60),CBAB(60),CBNC(60),CBN
      INTEGER   AX,AY,AV,AW,AZ
      CCMMCN   /A/AX,AY,AV,AW,AZ
   89 FCRMAT(1H0,*NC DCUBLE CROSS MATCH*,1018)
   92 FCRMAT(1H0,2116)
   93 FCRMAT(15X,1016)
   94 FCRMAT(1H0,* DEMAND  DAY   NC *,16, 4X,*CPN*,8X,*DBN*,8X,*PPN*,8X,*
     1PBN*,6X,*STATUS*)
   95 FCRMAT(1H0,*DEMAND  LIST   OF  THE  CAY *,/(22X,5I10))
   96 FCRMAT(1H0,*ASINED  CAY  NO  *,16,14X,*RPN*,7X,*PBN1*,7X,*PBN2*)
   97 FCRMAT(1H0,*  ASINED  LIST  CF  THE  DAY *,/(30X,3I10))
   98 FCRMAT(1H0,1018)
  100 FCRMAT(1H0,10I10)
  101 FCRMAT(1H0,* MATCH MATRIX OF THE DAY  *,*  PBN*,7X,*AGE*,6X,*PRPN*
     1,6X,*SNFN*,5X,*CMSTATUS*,/(22X,511C))
  105 FCRMAT(5X,* ----------------------------------------------*,1016)
  108 FCRMAT(1H1,14X,*RESULTS WITH SINGLE CROSS MATCH,1 DAY HOLD*,//)
  109 FORMAT(///,14X,*RESULTS WITH DCUBLE CROSS MATCH,1 DAY HOLD*,//)
  110 FCRMAT(5X,1518)
  115 FCRMAT(5X,2016)
  120 FCRMAT(1H0,14X,8F6.2,2F7.0,F6.2)
  122 FCRMAT(15X,*NO DCUBLE  CROSS  MATCH  CN  DAY  NO ...*,814)
  125 FCRMAT(5X,3014)
      IXX=C
      PRINT 108
      NFCCMS=1
  123 CCNTINUE
      SIMNC=13.
      SIMNC=1.
      NC=14
  124 CCNTINUE
      AAN=1
      CALL  INRANC(AAN)
```

```
10 DC 25 I=1,21
   PROCUR(I)=0
25 IST(I)=0
   DC 35 I=1,50
   CM(I,1)=-1
   DM(I,2)=-1
   CM(I,3)=-1
   CM(I,4)=-1
   CM(I,5)=-1
35 CCNTINUE
   DC 45 I=1,60
   DREN(I)=-1
   NLCALC(I)=-1
   IF(SIMNC.GT.24.)INTAKE(I)=-1
   CEMAND(I)=-1
   CENA(I)=-1
   CENE(I)=-1
   CENC(I)=-1
   RABN(I)=-1
45 RECMEN(I)=-1
   DC 65 I=1,700
   ASINED(I,1)=-1
   ASINED(I,2)=-1
65 ASINED(I,3)=-1
   DC 75 I=1,900
   MM(I,1)=-1
   MM(I,2)=-1
   MM(I,3)=-1
   MM(I,4)=-1
75    MM(I,5)=-1
   TEC=0
   TAP=0
   TSORTG=0
   TCALL=0
   TUNCAL=0
   TCNUSE=C
   TBDAP=0
76 TCLECT=0
   ASINC=0
   CCATE=0
   TUNCEW=C
   TCNUGW=0
   TAGW=0
   KZ=C
   UNASNC=C
   TESA=0
   MM=C
   LR=0
   LC=0
   TST=0
   LA=1
   FFN=1
   AEN=1
   IACCN=0
   LX=0
   DN=1
```

```
      N4=C
      LSP=C
      NTLW=0
      INC=CN-(CN/3)*3
    1 IF(INCON.EC.(-1)) GC TO 50
C     ****************************************************************
C     INITIAL STOCKING
C     ****************************************************************
      CC 5 I=18,21
    5 IST(I)=C
      CC 30 L=1,17
      K=18-L
      IST(K)=RNDYX(AX)*4
      IN=IST(K)
      IF(IN.EC.0) GC TO 3
      N3=N4+1
   15 N4=N4+IN
      CC 20 I=N3,N4
      PEN=I
      MM(PEN,1)=I
      MM(PEN,2)=K
      MM(PEN,3)=C
   20 CCNTINUE
   30 CCNTINUE
      INCCN=-1
      TST=TST+N4
      UNASNC=UNASND+N4
      K4=N4
C     ****************************************************************
C     PROCUREMENT
C     ****************************************************************
      IF(IXX.NE.C) GO TO 34
      IF(SIMNC.NE.1.) GO TO 34
      READ 33,(INTAKE(I),I=1,30)
   33 FCRMAT(20I4)
   34 CCNTINUE
   50 CCNTINUE
      LF=CN/3
      INC=CN-3*LF
      IF(INC.EC.0)INC=3
      COLECT=RNDYX(AX)*31.
      IF(IXX.NE.C) GC TC 37
      IF(SIMNC.EC.13.)INTAKE(CN)=COLECT
   37 CCNTINUE
      IF(SIMNC.LE.24.)COLECT=INTAKE(CN)
      IF(COLECT.EC.0)COLECT=1
      PROCUR(I)=COLECT
      INTAKE(CN)=COLECT
   36 K3=K4+1
      K4=K4+COLECT
      CC 40 I=K3,K4
      PEN=I
      MM(I,1)=I
      MM(I,2)=1
      MM(I,3)=0
   40 CONTINUE
```

```
   41 TCLECT=K4
      TST=TST+CCLECT
      LNASNC=UNASNC+CCLECT
      JX=6
      JY=6
C     ****************************************************************
C         RETLRN  CF  CALLEC  ELT  UNUSEC  BCTTLES
C     ----------------------------------------------------------------
      IF(CN.LE.4)  GC TO 71C
      BR=NLCALC(CN-3)
      NCBR=RNCYV(AV)*BR
      LX=NCBR
      LY=C
      IF(LX.EG.C)  GC TC 69C
      IF(IAC.EG.1)  GC TC 63C
      IF(IAC.EG.2)  GC TC 65C
      LY=CENC(3)-5
      IF(LY.LE.0)  GC TC 69C
      IF(LX.GT.LY)LX=LY
      CC 620 JU=1,LX
      REN=CENC(JL+5)
      MM(REN,3)=C
      MM(REN,4)=0
      IF(MM(REN,2).LE.17)  GO TO 615
      MM(REN,5)=0
      TCNUGW=TCNUGW+1
      CCATE=CCATE+1
      GC TC 620
  615 UNASNC=UNASNC+1
      RAEN(JX)=REN
      JX=JX+1
      MM(REN,5)=-1
  620 CCNTINUE
      GC TC 700
  630 LY=CENA(3)-5
      IF(LY.LE.0)  GC TC 69C
      IF(LX.GT.LY)LX=LY
      CC 640 JV=1,LX
      REN=CBNA(JV+5)
      MM(REN,3)=C
      MM(REN,4)=0
      IF(MM(REN,2).LE.17)  CC TO 635
      MM(REN,5)=C
      TCNUGW=TCNUGW+1
      CCATE=CCATE+1
      GC TC 640
  635 LNASNC=LNASNC+1
      RAEN(JX)=REN
      JX=JX+1
      MM(REN,5)=-1
  640 CCNTINUE
      GC TC 700
  650 LY=CENB(3)-5
      IF(LY.LE.0)  GC TC 69C
      IF(LX.GT.LY)LX=LY
      CC 660 JW=1,LX
```

```
      RBN=CBNE(JW+5)
         NN(RBN,3)=C
      NN(REN,4)=0
      IF(NN(REN,2).LT.17)  GO TO 655
      NN(REN,3)=0
      TCNLGW=TCNUGW+1
      CDATE=CDATE+1
      GC TC 660
  655 LNASNC=LNASNC+1
      RAEN(JX)=REN
      JX=JX+1
      NN(REN,5)=-1
  660 CCNTINUE
      GC TC 7
  690 CCNTINUE
C     PRINT  495,CN,INC
  695 FCRMAT(1H ,*NC RETURN  OF  CALLED  BOTTLES  ON  DAY NO--*,10I6)
      IF(LY.LE.0)  GO TO 705
  700 TCNUSE=TCNUSE+LX
  705 RAEN(3)=JX-1
      RABN(1)=CN
      RAEN(4)=3
    * LKR=RABN(3)
  710 CCNTINUE
      IF(CN.EC.1)  GO TO 290
      LK=5
      LC=C
      LKK=IZ+5
      CC 280 I=6,IZ
      AXX=RNEYZ(AZ)
      BXX=RNDYW(AW)
      IF(AXX.LT.BXX)  GO TO 278
      CEN=CRBN(I)
      LC=LC+1
      IF(I.EQ.IZ)  LKK=LC+5
      LHH=NM(CEN,5)
      IF(LHH.EC.1)  GO TO 250
      IF(LHH.NE.2)  GO TO 279
      KAS=ASINEC(CEN,3)
      IF(KAS.LT.1)  GO TO 250
      ASINEC(CEN,3)=C
      ASINEC(KAS,3)=C
      NN(CEN,4)=-2
      NN(KAS,4)=-2
      IF(CEN.LT.KAS)  GO TC 230
      NN(CEN,5)=1
      CEN=KAS
      GC TC 250
  230 NN(KAS,5)=1
  250 NN(CEN,5)=2
  255 LK=LK+1
      IF(INC.EC.1)  GO TO 260
      IF(INC.EC.2)  GO TO 270
      CBNC(LK)=CEN
      IF(LK.LT.LKK)  GO TO 280
  257 CBNC(1)=CN
```

```
      CBNC(2)=INC
      CBNC(3)=LKK
      GC TC 90
 260  CBNA(LK)=CBN
      IF(LK.LT.LKK)  GC TO 280
 267  CBNA(1)=CN
      CBNA(2)=INC
      CBNA(3)=LKK
      GC TC 90
 270  CBNB(LK)=CBN
      IF(LK.LT.LKK)  GC TO 280
 277  CBNB(1)=CN
      CBNB(2)=INC
      CBNB(3)=LKK
      IF(I.EQ.IZ)  GC TC 90
 278  IF(I.LT.IZ)  GC TC 290
      IF(LC.EC.0)  GC TC 290
      LKK=LC+5
      GC TC (267,277,257),INC
 279  LC=LC-1
 280  CCNTINUE
 290  CCNTINUE
C     PRINT  295,CN
 295  FCRMAT(1H0,* NC ECTTLE CALLEC  CN  DAY  NUMBER-----*,10I6)
 300  FCRMAT(5X,3014,/)
  90  CCNTINUE
      TCALL=TCALL+LC
      NUCALC(CN)=LC
C     **************************************************************************
C     CANCELATICN  CF  RESERVATION
C     --------------------------------------------------------------------------
      IF(CN.EC.1)CC TC 600
      DC 590 I=6,IZ
      LF=DRBN(I)
      LS=MM(LP,5)
      IF(LS.EC.0)  GC TC 590
      IF(LS.EC.3)  GC TC 590
      IF(MM(LF,2).LE.17)  GC TO 520
      IF(LS.NE.2)  GC TO 515
      LPM=ASINEC(LF,2)
      IF(LPM.LF.C)  CC TC 515
      MM(LPM,5)=1
      ASINEC(LPM,3)=-2
      ASINEC(LP,3)=-2
 515  CCNTINUE
      MM(LF,5)=0
      TLNCCW=TUNCGW+1
      CCATE=CCATE+1
      GO TO 590
 520  IF(LS.NE.1)  GC TC 540
      RABN(JX)=LP
      MM(LF,3)=0
      MM(LP,5)=-2
      CC TC 580
 540  IF(LS.NE.2)  GC TC 590
      LPA=ASINEC(LF,3)
```

```fortran
      IF(NN(LFA,5).LE.0)  GC TO 550
      NN(LF,3)=NN(LF,4)
      NN(LF,4)=-2
      NN(LF,5)=3
      RECMEN(JY)=LF
      JY=JY+1
      GC TC 560
  550 LFA=LF
  560 CCNTINUE
      RABN(JX)=LFA
      NN(LFA,3)=0
      NN(LFA,4)=-2
      NN(LFA,5)=-2
      ASINED(LPA,2)=-2
      ASINED(LFA,3)=-2
      ASINEC(LP,2)=LFA
      ASINEC(LP,3)=-2
  580 TUNCAL=TUNCAL+3
      UNASAC=UNASAC+3
      JX=JX+1
  590 CCNTINUE
      RABN(1)=CN
      RABN(4)=5
      RABN(3)=JX-1
      LKR=RABN(3)
      RECMEN(1)=CN
      RECMEN(4)=7
      RECMEN(3)=JY-1
      LKS=RECMEN(3)
  600 CCNTINUE
      IF(CN.NE.1)  GC TO 56
C  ******************************************************************
C     CEMAND
C  ******************************************************************
   55 N2=0
      K3=0
   56 CCNTINUE
      NCPR=1.+RNCYX(AX)*13.
      TNP=TNP+NCPR
      NRR=0
      N1=N2+1
   57 N2=N2+NCPR
      NRC=0
      KZ=5
      IZ=6
      CC 80 J=N1,N2
      NRC=NRC+1
      CPN=NRC
      FPN=J
      RN=1.+RNCYY(AY)*6.
C  ******************************************************************
C     DN ENTRY
C  ******************************************************************
      NEREP=RN
      K1=K2+1
   60 K2=K2+NERBP
```

```
      CC 7C KK=K1,K2
   64 NRR=NRR+1
      CEN=KK
      CM(NRR,1)=NRC
      CM(NRR,2)=NRR
      TEC=TED+1
      IF(UNASNC.GT.0)  GC TC 66
C     ***************************************************************************
C     SHCRTAGE
C     ***************************************************************************
      CM(NRR,3)=0
      CM(NRR,4)=0
      CM(NRR,5)=0
      TSCRTG=TSCRTC+1
      GC TC 70
C     ***************************************************************************
C     ASSIGNMENT  ENTRY
C     ***************************************************************************
   66 INDEX=1
      IF(CN.EC.1)  GC TO 168
      KRP=0
      KM=RAEN(3)
      IF(KM.LT.6)  GC TC 167
      NA=KZ+1
      IF(NA.GT.KM)  CC TC 167
      IF(KZ.GT.KM)  CC TC 167
      CC 67 KR=NA,KM
      KN=RABN(KR)
      KZ=KZ+1
      IF(MM(KN,2).GT.17)  GC TO 67
      ABN=KN
      INDEX=0
      KRP=KR
      ASINED(ABN,1)=J
      ASINED(ABN,2)=ABN
      GC TC 169
   67 CCNTINUE
  167 ABN=ASINC+1
  168 ASINEC(CBN,2)=ABN
      ASINEC(CBN,1)=J
  169 UNASNC=UNASNC-1
      CRBN(IZ)=ABN
      IF(UNASNC.LT.0)UNASNC=0
      ASINEC(CBN,2)=ABN
      CM(NRR,3)=J
      CM(NRR,4)=ABN
      CM(NRR,5)=1
      MM(ABN,5)=1
      MM(ABN,3)=J
      TESA=TBSA+1
      IZ=IZ+1
      TPSA=J
   69 CCNTINUE
      IF(INDEX.EC.0)  GC TC 70
      ABN=ABN+1
      ASINC=ASINC+1
```

```
   7C CONTINUE
   80 CONTINUE
      DRBN(1)=DN
      IZ=IZ-1
      DRBN(3)=IZ
      DRBN(2)=6
      DEMAND(DN)=NRR
      IF(DN.EC.1)  GC TO 134
      IF(KN.LE.KRP)  GC TO 134
      LW=KN-KRP
      NTLW=NTLW+LW
      UNASNC=UNASNC-LW
      IF(UNASNC.LT.0)UNASNC=0
  134 CONTINUE
      IF(NFDCNS.EC.1)  GC TC 799
C    ******************************************************************
C    DCUBLE  CROSS  MATCHING
C    ******************************************************************
  721 N5=TECAP+1
      KX=C
      N6=TECAP+(ASINC-TECAP)/2
  722 LR=N6
      IF(N6.LE.N5)  GO TC 788
      KLL=6
      KP=RCCMEN(3)
      DC 767 NN=N5,N6
      NR1=NN
      IF(DN.LE.1)  GC TC 745
      IF(KP.LT.6)  GC TC 745
      IF(KLL.GT.KP)  GC TO 745
      NR1=RDCMBN(KLL)
      KLL=KLL+1
  745 IF(MM(NR1,5).EC.1)  GC TC 753
      NR1=NR1+1
      IF(NR1.GT.ASINC)  GO TC 788
      GC TC 745
  753 NR=MM(NR1,2)
      JS=MM(NR1,5)
  763 NR3=MM(LR,2)
      JR=MM(LR,5)
      JC=NR-NR3
      IF(JC.LT.NC)  GC TC 766
      IF(JS.NE.1)  GC TO 767
      IF(JR.NE.1)  GC TC 766
  764 NP1=NR3
      KT=LR-1
      NP2=MM(KT,2)
      IF(NP1.NE.NP2)  GO TC 765
      NP3=MM(KT,5)
      IF(NP3.EQ.2)  GC TC 765
      LR=LR-1
      GC TC 764
  765 NR2=LR
      MM(NR1,4)=MM(NP2,3)
      MM(NR2,4)=MM(NR1,3)
      MM(NR1,5)=2
```

```
      MM(NR2,5)=2
      ASINED(NR1,3)=NR2
      ASINED(NR2,3)=NR1
      LR=LR+1
      TEDAP=TEDAP+1
      KX=KX+1
      GC TC 767
  766 LR1=LR+1
      LR=LR1
      IF(LR.GT.ASINC)  GC TC 788
      GC TC 763
  767 CONTINUE
  788 IF(KX.NE.0)  GC TC 789
      MM=1CCO
  789 CONTINUE
C     ------------------------------------------------------------
C     TCTAL  WASTE  CALCULATION
C     ------------------------------------------------------------
      IF(TCLECT.GT.900)  GC TO 1000
      DC 410 IA=1,TCLECP
      KA=MM(IA,2)
      IF(KA.LT.18)  GC TC 500
      IF(MM(IA,5).GE.0)  GC TO 405
      CCATE=CCATE+1
      UNASNC=UNASNC-1
      IF(UNASNC.LT.0)  UNASNC=0
      TAGW=TAGW+1
      MM(IA,5)=0
  405 LA=LA+1
  410 CONTINUE
  500 CONTINUE
      DC 91 IT=1,TCLECT
   91 MM(IT,2)=MM(IT,2)+1
C     ************************************************************
C     PRINTING  RESULTS
C     ************************************************************
      LSP=LSP+UNASNC
      AVINVP=LSP/CN
C     PRINT  115,CN,CCLECT,TCLECT,TNP,NRR,TEC,TBSA,ASINC,TUNCAL,TBDAP,TS
C    1CRTG,TCALL,TCNUSE,CCATE,TUNCGW,TCNUGW,TAGW,LX,NTLW,UNASNC
      CN=CN+1
      IF(CN.LE.30)  GC TC 50
      AWASTE=CCATE
      AVBCPP=TEC/TNP
      SCRTP=FLCAT(TSCRTG)/FLOAT(TEC)*100.
      WASTPC=AWASTE/FLCAT(TEC)*100.
      WASTPC=AWASTE/FLCAT(TCLECT)*100.
      CALLP=FLCAT(TCALL)/FLCAT(TBSA)*100.
      UNCALP=FLCAT(TCNUSE)/FLOAT(TCALL)*100.
      UNRESP=FLCAT(TUNCAL)/FLOAT(TBSA)*100.
      LEFFIN=(FLCAT(TBSA)-FLCAT(ASINC))/FLCAT(TBSA)*100.
      PRINT  120,SIMNC,AVBCPP,SCRTP,WASTPC,WASTPC,CALLP,UNCALP,UNRESP,AV
     1INVP,AWASTE,LEFFIN
      SIMNC=SIMNC+1.
      NC=NC-1
      IF(NC.GE.3)  GC TO 124
```

```
      NFCCMS=NFCCMS+1
      IXX=IXX+1
      IF(NFCCMS.EC.2)PRINT  109
      IF(NFCCMS.EQ.2)  GC TC 123
1000  STCP
      END
$IBFTC RNCYX
      FUNCTION  RNCYX(XX)
      INTEGER  A,XX
      DATA  A/186277/
      XX=A*XX
      AY=XX
      RNCYX=AY/34359738638.
      RETURN
      END
$IBFTC RNCYY
      FUNCTICN  RNCYY(YY)
      INTEGER  B,YY
      DATA  B/186285/
      YY=B*YY
      BY=YY
      RNCYY=BY/34359738638.
      RETURN
      END
$IBFTC RNCYV
      FUNCTICN  RNCYV(VV)
      INTEGER  C,VV
      DATA  C/186293/
      VV=C*VV
      CY=VV
      RNCYV=CY/34359738638.
      RETURN
      END
$IBFTC RNCYW
      FUNCTICN  RNCYW(WW)
      INTEGER  C,WW
      DATA  C/186301/
      WW=C*WW
      CY=WW
      RNCYW=CY/34359738638.
      RETURN
      END
$IBFTC RNCYZ
      FUNCTICN  RNCYZ(ZZ)
      INTEGER  E,ZZ
      DATA  E/186309/
      ZZ=E*ZZ
      EY=ZZ
      RNCYZ=EY/34359738638.
      RETURN
      END
$IBFTC INRANC
      SUBROUTINE  INRANC(NNN)
      INTEGER  AX,IY,AV,AW,AZ
      CCMMCN  /A/AX,IY,AV,IW,AZ
      IF(NNN.EC.1)  GO TO 5C
```

```
        GO TO 60
 50  AX=11750920161
     AY=27594084237
     AV=10796931217
     AW=17669802561
     AZ=560227513
 60  RN1=RNDYX(AX)
     RN2=RNDYY(AY)
     RN3=RNDYV(AV)
     RN4=RNDYW(AW)
     RN5=RNDYZ(AZ)
     NNN=NNN+1
     RETURN
     END
SENTRY
```